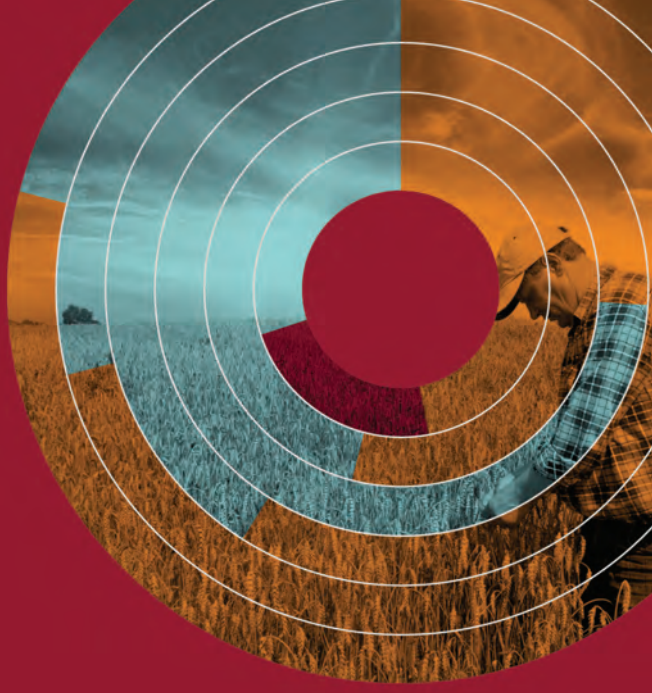
Australian Government
Department of Agriculture



Multi-Criteria Analysis Shell

MCAS-S

For Spatial Decision Support

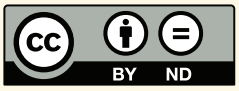
User Guide

Version 3.1 – 2014

A product of the MCAS-S Development Partnership

Disclaimer and licensing

The Commonwealth of Australia, acting through the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) is making available the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) software under the Creative Commons Attribution-NoDerivs 3.0 Australia License.



This is a standard form license which allows you to copy, distribute, and display the work provided you attribute the original author and do not alter, transform or build upon this work. A summary of the licence terms is available from creativecommons.org/licenses/by-nd/3.0/au. The full licence terms are available from creativecommons.org/licenses/by-nd/3.0/au/legalcode.

This publication (and any material sourced from it) should be attributed as: MCAS-S development partnership 2014, *Multi-Criteria Analysis Shell for Spatial Decision Support MCAS-S version 3.1 User guide*, ABARES, Canberra, February. CC BY 3.0.

ABARES does not represent or warrant that calculations in MCAS-S are accurate, correct, useful or meaningful, and does not accept any responsibility for the use of MCAS-S in either the form as supplied or as modified by others.

ABARES may at any time, at its discretion, amend, vary or modify these terms and conditions. Modifications to these terms and conditions will be effective immediately and any subsequent use of MCAS-S will constitute acceptance of the modifications.

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

Postal address GPO Box 1563 Canberra ACT 2601
Switchboard +61 2 6272 2010
Facsimile +61 2 6272 2001
Email info.abares@daff.gov.au
Web daff.gov.au/abares

Copies available from:
Web daff.gov.au/abares/data/mcass
Email land_management@daff.gov.au

© Commonwealth of Australia 2014

This work is copyright. The *Copyright Act 1968* permits fair dealing for study, research, news reporting, criticism or review. Selected passages, tables or diagrams may be reproduced for such purposes provided acknowledgment of the source is included. Major extracts or the entire document may not be reproduced by any process without the written permission of the Executive Director, ABARES.

Acknowledgements

ABARES would like to acknowledge the input of the MCAS-S development partnership members including Barry Consulting, New South Wales Office of Environment and Heritage particularly Tom Barrett, the National Environmental Research Plan Landscapes and Policy Hub, and the Australian Collaborative Land Use and Management Program.

Funding for version 3.1 was provided by the National Environmental Research Plan Landscapes and Policy Hub University of Tasmania.

CONTENTS

1 Introduction 5

1.1 Who can use this decision support tool? 5
1.2 Changes since MCAS-S version 3.0 6

2 Getting started 7

2.1 System requirements 7
2.2 Installation 7
2.3 Opening a project 8
2.4 Creating a new project or saving a project 9
2.5 Introduction to the display workspace: available features and functions 10

3 Multi-criteria analysis 12

4 Step 1: Define the objective and decision criteria 14

5 Step 2: Assemble data inputs 17

5.1 Primary input data 17
5.1.1 Categorical data 18
5.1.2 Continuous data 19
5.1.3 Time-series data 19
5.2 Overlay data 20
5.3 Mask data 21
5.3.1 Mask view only 22
5.3.2 Mask view and data 23
5.4 Classified data 23
5.5 Preparing your own data 24
5.5.1 Primary data 25
5.5.2 Overlay data 27
5.5.3 Mask data 28
5.5.4 Metadata files 28
5.6 Creating user layers 29

6 Step 3: Explore and combine data 32

6.1 Setting up the MCAS-S workspace 32
6.1.1 Moving data layers 32
6.1.2 Resize data layers 32
6.1.3 Delete layers 32
6.1.4 Zoom options 33

6.2 Classifying data 33
6.2.1 Classifying continuous data 33
6.2.2 Classifying categorical data 37
6.2.3 Reclassifying data to a new order 40
6.3 Comparing data 41
6.3.1 Two-way comparison 41
6.3.2 Multi-way comparison 45
6.3.3 Using a layer as an underlay 48
6.4 Combining data (composite development) 48
6.4.1 Manual (default option) 49
6.4.2 Function 51
6.4.3 Analytical hierarchy process 52
6.5 Other features 56
6.5.1 Viewer window 56
6.5.2 Changing class colours and names 58
6.5.3 Adding colour ramps 59

7 Step 4: Develop options 60

7.1 Sensitivity analysis 61

8 Step 5: Review and report 65

8.1 Exporting 65
8.2 Reporting 66
8.2.1 Report by region 66
8.2.2 Report by point 69
8.2.3 Correlation report 69
8.2.4 Showing a map in Google Earth 69
8.3 Keeping records 69
8.3.1 Copying a log as text 69
8.3.2 Copying a layer as an image 69
8.3.3 Saving an image, legend and histogram 69
8.3.4 Printing 70
8.3.5 Restoring a previous version of the MCAS-S workspace from the History folder 70
8.3.6 Other software for keeping records 70

9 Errors and feedback 71

9.1 Common error notifications 71
9.2 Checking and correcting common errors 72
9.2.1 MCAS-S software fails to install or is unable to be opened for first use 72
9.2.2 An error message is repeatedly encountered in an MCAS-S project 72

References and further reading 74

Glossary and index 75

1 INTRODUCTION

Informed and transparent decision-making often requires combining and analysing mapped information to help stakeholders assess issues, options and trade-offs. To address this need, the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) software has been created by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) with the support of the MCAS-S Development Partnership. The MCAS-S Development Partners are organisations committed to using and improving the MCAS-S software. The partnership was formed in 2013.

MCAS-S is a powerful, easy-to-use spatial decision support tool designed to help visualise and combine mapped information in a flexible, interactive way. MCAS-S can be used to construct a project at any scale and resolution, and the ability to show 'live updates' is particularly helpful at workshops.

The sample project installed with this software includes a limited selection of Australian national map layers which are ready for use. More data are available from the MCAS-S website daff.gov.au/abares/data/mcass. Users can also format their own data to use in MCAS-S projects.

1.1 Who can use this decision support tool?

MCAS-S is designed for decision-makers. It shows transparently how mapped information can be combined to meet an objective. MCAS-S allows stakeholders to see the effects of the decisions they make.

Successful use of the software does not require Geographic Information Systems (GIS) programming, removing the usual technical obstacles to non-GIS users in accessing and analysing spatial information. MCAS-S enables users to:

- view and classify map layers
- adapt and combine map layers in ways that provide insight into key relationships and questions
- look at alternative views quickly and easily using interactive 'live-update' mapping options
- produce statistical reports for regions (for example, catchments) quickly and simply.

More specifically, as a map viewer and a flexible, easy-to-use spatial-analysis tool, MCAS-S software allows users to:

- select map layers, drag them into the display workspace, classify maps as needed and create composite datasets by combining selected layers
- see multiple map layers simultaneously in the display workspace, modify values within the datasets and see both the relationships between the datasets and the flow-on effects of modifying spatial data values,

- carry out two-way and multi-way comparisons to form a cognitive flow diagram of maps, display their relationship to each other on the screen and interactively manipulate them, and
- document results and the decision-making process, as well as assumptions.

An advantage of the software is that it selects analysis functions and interface panels according to map type. The display and analysis functions change automatically when the user accesses different types of spatial display maps, such as raw input data, composite indicators, and two-way and multi-way comparisons of datasets. These features make the MCAS-S interface very intuitive to use.

Since users are able to carry out potentially inappropriate and invalid data associations, any assessments using MCAS-S should take advantage of expert opinion and stakeholder advice, and results should be clearly articulated in the context of data dependencies, assumptions, actions and user perspectives.

More sophisticated use of the MCAS-S software can facilitate spatial multi-criteria analysis (MCA)—a process designed to improve decision-making by using diverse factual information, value judgement, opinion, and policy and management goals. In this context, transparent and logical treatment of information is important. MCA is discussed in more detail in section 3.

1.2 Changes since MCAS-S version 3.0

This new version of the MCAS-S software (version 3.1) includes the following new features:

- An improved workspace with new toolbars and zoom and pan options, multiple layers can be added, resized, aligned, exported and deleted at once, and new colour ramps have been added.
- More options for classifying data layers include standard deviation, natural breaks and a 'reclass' classification for values or classes of interest which don't fall at one end of an existing scale.
- Overlays can be included in analysis by creating distance from points and lines turning overlays into primary layers.
- Editing composite functions is now possible through the function calculator.
- Multi-ways now show a 'coincidence count' of how many input criteria are met.
- Users can report on values at points and find the correlation between two layers through a 'correlation report'.
- Time stamped versions of MCAS-S projects are saved in the History folder helping to keep track of decisions and allowing users to revert to a previous option.

More detailed instructions on all functions are included in the manual. We hope you enjoy using the new version.

2 GETTING STARTED

MCAS-S runs on most standard computers. As soon as the software is installed users can begin mapping using the included MCAS-S sample project files. The MCAS-S sample project and the selection of Australian national map layers included with the software are used as examples throughout this user guide.

2.1 System requirements

MCAS-S requires the following:

- Windows (NT, 2000, XP or later)
- 2 GB of RAM (minimum recommended)
- 1 GHz or faster CPU
- 1 GB of disk space for program and included sample project layers.

2.2 Installation

The MCAS-S installer and user guide can be downloaded from the MCAS-S website. A more comprehensive selection of Australian national map layers is also available from the MCAS-S website. The MCAS-S installer can be saved on your computer in case the program needs to be repaired at a later date.

Double-clicking on the MCAS installer will bring up a series of instructions to install the MCAS-S software. The software should be installed on a local hard drive. The default location is C:\Program Files\ABARES\Multi-Criteria Analysis Shell v3.1. The sample project will automatically install in a folder called *sample* inside this same folder. MCAS-S projects to be used and modified will need to be saved alongside their related data folder in the user's working directory. Installing the software will add the MCAS-S icon to the desktop (figure 1) and, by double-clicking the icon, MCAS-S will start, and the screen shown in figure 2 will appear.

TIP: Check the website to make sure you have the newest MCAS-S version 3.1 installer. Some updates have been made as requested by MCAS-S users. When updating to the newest release of 3.1 make sure to uninstall older versions of MCAS-S 3.1 first. It is still possible to run older versions of MCAS-S (such as 2.1 and 3.0) on the same computer.

FIGURE 1 The MCAS-S desktop icon shows that the software has been installed

FIGURE 2 MCAS-S interface

The text located at the left-hand side of the screen, provides links to the MCAS-S user guide, the MCAS-S website and also gives more information on the development partners. To begin work, an MCAS-S project, either new or existing, must be open.

Data folders and projects must be installed side by side on the working drive (this does not have to be where the software is installed). To install an extra data folder, such as the Australian National Map layers (which are available from daff.gov.au/abares/data/mcass), check that there is enough available space on your drive (the 2 km grid Australian national map layers require 4 GB). Download or copy and save the *Data* folder and project to the working directory. The data and project need to be saved in the same folder.

2.3 Opening a project

Pre-installed sample MCAS-S projects, or the user's own saved projects, can be opened by going to the *File* drop-down menu, selecting *Open*, and navigating to where the project has been saved. Alternatively, open projects by navigating directly to these folders (for example, through Windows Explorer) and double-clicking on project filenames. There is a blank, and completed, 'soils at risk' sample project in the MCAS-S program folder which, if saved on the C: drive, can be found at C:/Program Files/ABARES/Multi-criteria Shell v3.1/Sample.

Note that classifications may be lost when opening a project saved using version 3.0 of MCAS-S.

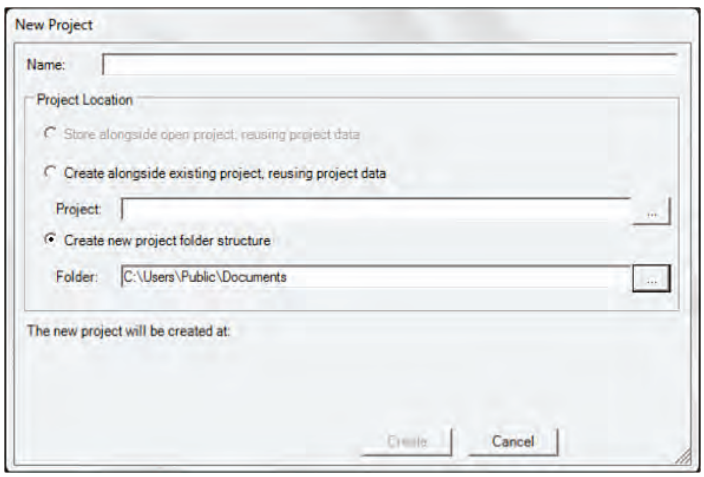
When opening an existing project in MCAS-S version 3.1 you will need to compare the old project with the new version and reclassify layers where necessary. Some masks and overlays may not save between versions and will need to be reselected if missing.

2.4 Creating a new project or saving a project

A new project is created using the *File* drop-down menu and by selecting *New*. There are then several options (figure 3).

- The first option—*Store alongside open project, reusing project data*—is the same as the *Save as* option that allows the user to modify a project and save it as a new version. This option is available when working in a project.
- The second option—*Create alongside existing project, reusing project data*—allows a new blank project to be created using an existing dataset (*Data* folder). This involves simply naming the new project and then browsing to the required dataset.
- The third option—*Create new project folder structure*—allows a new project and a new dataset (*Data* folder) to be created in a specified directory. This option is for users with their own project data layers. It creates a set of empty folders ready to be filled with data relevant to the new project. The folders will need to be populated as described in section 5.5 'Preparing your own data'. The folder can be populated with pre-processed user data (see section 5.5) or by using a subset of an existing, larger dataset, copying and pasting from an existing dataset to the *Primary* data, *Overlay* data and *Mask* data project files of the new project (note that GIS software may be needed to copy individual grids to avoid corruption, so it is safer to copy over entire folders). Once the new project is open, the primary data grids, overlays and masks saved in the Data folder will be available for use in your project.

FIGURE 3 Options for creating a New Project

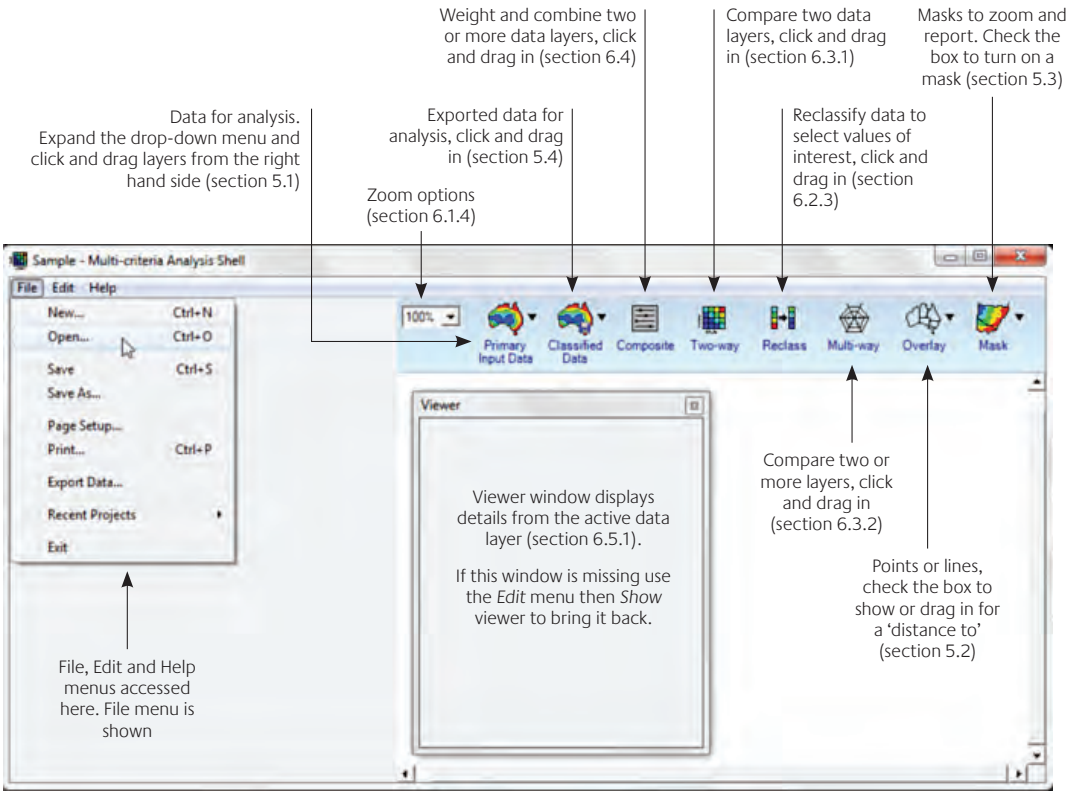


To save an open project use the *File* drop-down menu and select *Save*. This will also save a copy in the *History* folder. To save a copy of an open project select *Save as*. When prompted by the *Save project as* window select the first option to keep working in the same place, or, select the second option to create a new copy of the project and data. The data folder may be large so ensure there is enough space in the new location before saving.

2.5 Introduction to the display workspace: available features and functions

MCAS-S software has functions to allow users to interact with spatial data at any stage of the project. Figures 4 and 6 show the MCAS-S display workspace and where to find key functions once a project is open.

FIGURE 4 View of the MCAS-S workspace, location of common MCAS-S functions and cross-references to further information


Weight and combine two or more data layers, click and drag in (section 6.4)
Compare two data layers, click and drag in (section 6.3.1)
Masks to zoom and report. Check the box to turn on a mask (section 5.3)
Data for analysis. Expand the drop-down menu and click and drag layers from the right hand side (section 5.1)
Exported data for analysis, click and drag in (section 5.4)
Zoom options (section 6.1.4)
Reclassify data to select values of interest, click and drag in (section 6.2.3)
Sample - Multi-criteria Analysis Shell
File Edit Help
New... Ctrl+N
Open... Ctrl+O
Save Ctrl+S
Save As...
Page Setup...
Print... Ctrl+P
Export Data...
Recent Projects
Exit
100%
Primary Input Data
Classified Data
Composite
Two-way
Reclass
Multi-way
Overlay
Mask
Viewer
Viewer window displays details from the active data layer (section 6.5.1).
If this window is missing use the Edit menu then Show viewer to bring it back.
Compare two or more layers, click and drag in (section 6.3.2)
Points or lines, check the box to show or drag in for a 'distance to' (section 5.2)
File, Edit and Help menus accessed here. File menu is shown

Hover the mouse over functions in the top panel to see a tool tip with more information (figure 5).

FIGURE 5 Tool tip describing the Primary Input Data

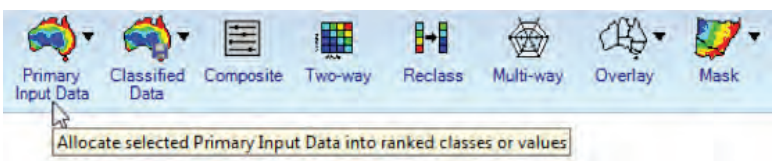
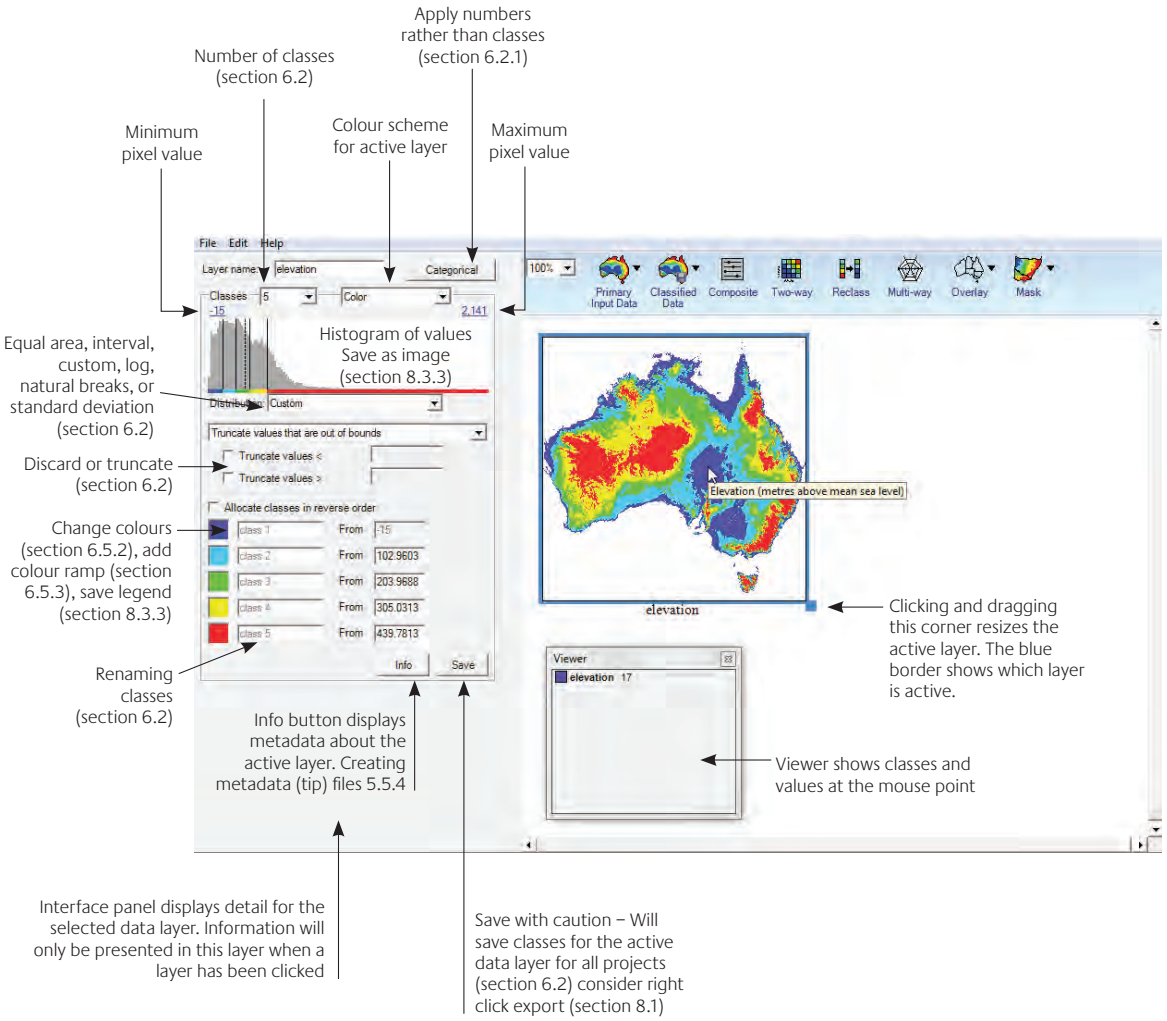


FIGURE 6 Location of MCAS-S functions in the left-hand side interface panel


Apply numbers rather than classes (section 6.2.1)
Number of classes (section 6.2)
Minimum pixel value
Colour scheme for active layer
Maximum pixel value
File Edit Help
Layer name elevation
Categorical
Classes 5
Color
-15
2,141
100%
Primary Input Data
Classified Data
Composite
Two-way
Reclass
Multi-way
Overlay
Mask
Histogram of values
Save as image
(section 8.3.3)
Equal area, interval, custom, log, natural breaks, or standard deviation (section 6.2)
Distribution Custom
Truncate values that are out of bounds
Discard or truncate (section 6.2)
Truncate values <
Truncate values >
Allocate classes in reverse order
Change colours (section 6.5.2), add colour ramp (section 6.5.3), save legend (section 8.3.3)
class 1 From -15
class 2 From 102.9603
class 3 From 203.9688
class 4 From 305.0313
class 5 From 439.7813
Renaming classes (section 6.2)
Info
Save
Elevation (metres above mean sea level)
elevation
Clicking and dragging this corner resizes the active layer. The blue border shows which layer is active.
Viewer
elevation 17
Viewer shows classes and values at the mouse point
Info button displays metadata about the active layer. Creating metadata (tip) files 5.5.4
Interface panel displays detail for the selected data layer. Information will only be presented in this layer when a layer has been clicked
Save with caution – Will save classes for the active data layer for all projects (section 6.2) consider right click export (section 8.1)

Note: The figure above shows locations of MCAS-S functions once a continuous primary data layer has been added and is selected. The right-hand side is referred to as the workspace.

3 MULTI-CRITERIA ANALYSIS

Spatial multi-criteria decision-making is rarely straightforward. Answering simple questions such as 'Where are soils at risk?' often requires the combination of diverse environmental, social and economic information along with value judgements and policy and management goals. Usually, there is no 'right' answer. In the end, justifiable conclusions depend on informed, systematic and transparent analysis.

Multi-criteria analysis (MCA) is one way of approaching the assessment of complex issues in coupled human–environment systems. It is widely applied in business, government and community decision-making, including in natural resource management.

MCA is a process to assist decision-makers—it does not do the decision-making, but it can be used to explore options and potential outcomes. It is important to think about how information quality and uncertainty are factored in and integrated with stakeholder viewpoints and biases. It is also important to consider how achievable the best possible outcome is and if there is any room for compromise. Each stage of the MCA process should be carried out rigorously, in parallel with stakeholder engagement. Matching the spatial and temporal scale of the input information and analysis to the issues and processes under consideration is also critical (Lesslie et al. 2008).

There are many variants of the general MCA approach, and the process can be used to address a variety of questions. Well-developed MCA approaches generally share a number of characteristics, such as:

- being highly flexible and relatively simple to use
- enabling the capture of quantitative and qualitative data and issues
- permitting the development of many scenarios
- allowing the exploration of trade-offs
- enabling the stakeholder to factor MCA results into the decision-making processes.

There are five key steps in the MCA assessment process (figure 7).

FIGURE 7 Steps in the MCA process

Reiterate where necessary
1. Define the objective and decision criteria
2. Assemble data inputs
3. Explore and combine data
4. Develop options
5. Review and report

This guide shows how MCAS-S can be used to support an MCA. Note that the MCAS-S tool is not restricted to use in MCA assessments. It can be used in any situation where there is the need to display, combine and investigate the relationships between spatial information.

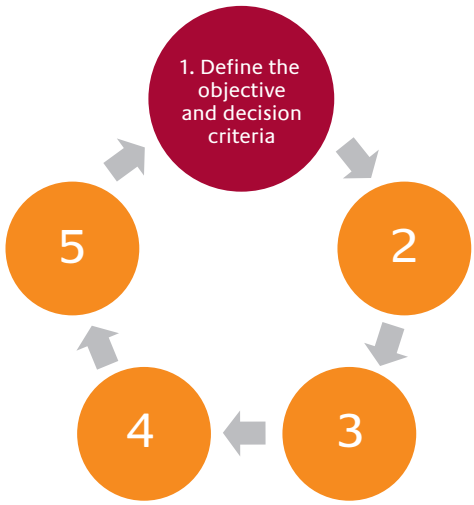
Throughout this manual a hypothetical example – identifying the location of 'soils at risk' shows how the MCAS-S software can be used in a multi-criteria analysis. Follow the development of the 'soils at risk' project in the boxed text in each section. The soils at risk example starts by identifying issues to consider (Box 1) and results in a complete MCAS-S project (Box 2). To begin see the next section 'Step 1: define the objective and decision criteria'.

4 STEP 1: DEFINE THE OBJECTIVE AND DECISION CRITERIA

The first step, 'Define the objective and decision criteria', is critical to success in an MCA process, as this frames the assessment and determines the subsequent steps in the process.

A 'means-to-an-end' diagram is a useful way to represent the objective and decision criteria, and to decide what data will be required and how they might be combined.

It is recommended that users consult a range of experts and stakeholders when developing a means-to-an-end diagram for a project, because this is one of the most important steps in the MCA process. Figure 8 shows an example of a simple means-to-an-end diagram, which is explained in more detail in Box 1, and shown as a completed MCAS-S project in Box 2.

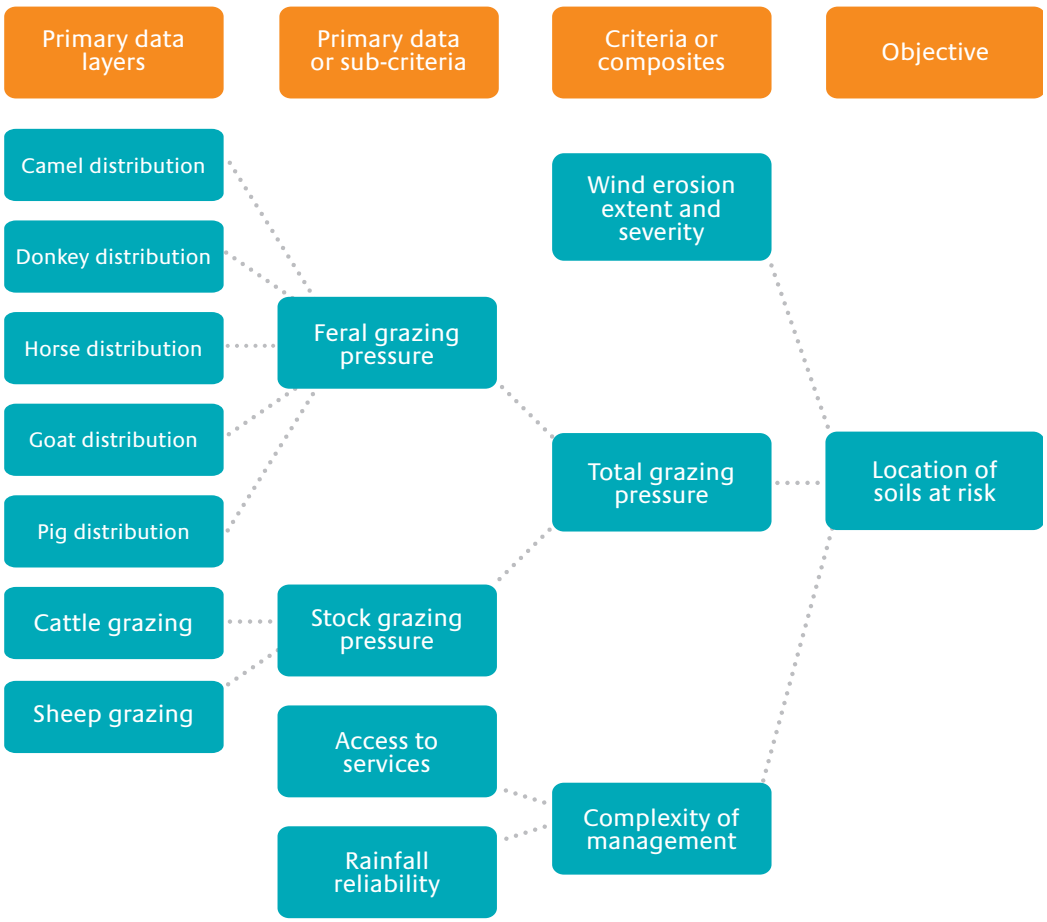


BOX 1 Hypothetical location of soils at risk—issues to consider

The example of 'Location of soils at risk' shows how the MCAS-S software can be used in a multi-criteria analysis. In this example, issues considered were the extent and severity of wind erosion, grazing pressure and the complexity of management. Figure 8 shows a simple means-to-an-end diagram for identifying where soils may be at risk of wind erosion through grazing. This example uses input data from the sample project, however the way in which this data has been combined to identify 'Location of Soils at Risk' of degradation is hypothetical and is included to show the user how an MCA could be structured. A number of other factors and input data could be taken into consideration in this context, such as ground cover, risk of water erosion, and land management practices.

Consultation with relevant experts is recommended to define the objective and decision criteria. In this case a workshop might include agronomists, social scientists, erosion, vegetation, climate and feral animals experts. Published examples are on the MCAS-S website.

FIGURE 8 A 'means-to-an-end' diagram can assist in framing a successful MCA process

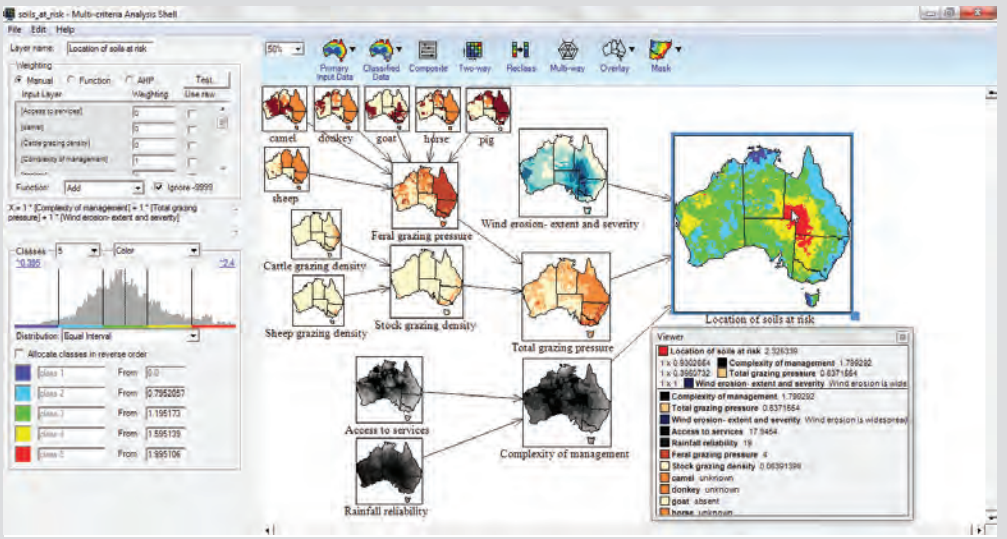


MCAS-S allows users to explore 'where questions' when appropriate spatial input data, including expert knowledge, are available and the thresholds of and linkages between the data are understood. MCAS-S enables the user to build a view that satisfies the stated objective by combining primary data layers into criteria or composites.

BOX 2 Hypothetical location of soils at risk—means-to-an-end diagram in MCAS-S

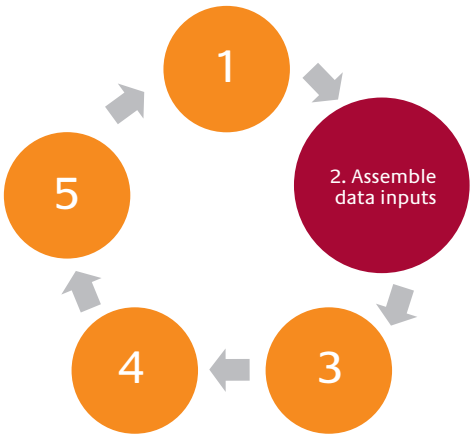
A means-to-an-end diagram, like the one in figure 8, can be represented by data layers in MCAS-S.

The 'Location of soils at risk' layer, is shown on the right-hand side of the figure below, with the input criteria and primary data layers shown on the left.



5 STEP 2: ASSEMBLE DATA INPUTS

Once MCAS-S has been installed and a blank or existing project has been opened, data can be added to the display workspace. Click and drag primary, classified, or overlay layers into the workspace, then check the box next to an overlay or mask of interest to apply the selection to all layers open in the project. Multiple layers can be added to the workspace by holding down the shift key when selecting layers and then dragging in all the selected layers.



TIP: To bring in a new data layer—click and drag

MCAS-S allows users to work with four types of data:

- primary input data—gridded raster input layers for display and for undertaking analysis
- classified data—gridded raster data layers created and exported using MCAS-S
- overlay data—contextual vector data, lines or points for visual reference (such as rivers or towns)
- mask data—gridded raster layers used to restrict the area of analysis or define regions for reporting.

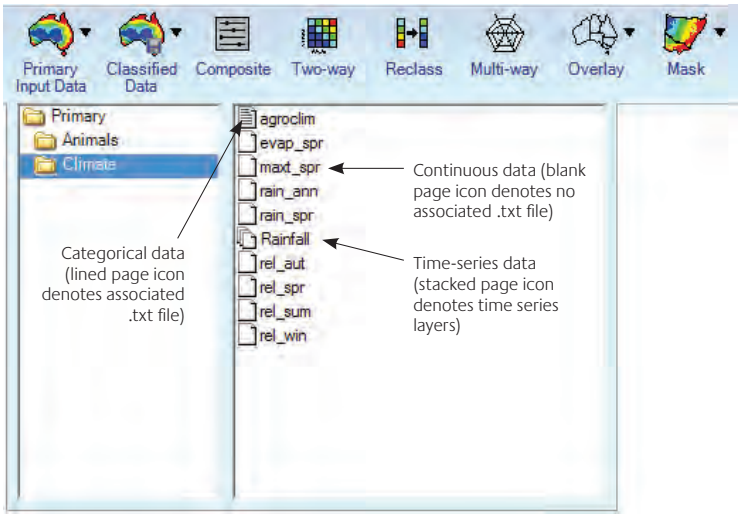
MCAS-S comes with a small sample set of Australian primary, overlay and mask data layers. However, the scope of the user's project may require other data inputs, which can be prepared for use in MCAS-S. Ready to use data packs can be downloaded from the MCAS-S website daff.gov.au/abares/data/mcass. Users should ensure that any data packs which are downloaded or created conform to the folder structure shown in section 5.5.

5.1 Primary input data

The *Primary* folder contains data layers for display and analysis.

Primary data layers are selected from a drop-down menu (under the heading *Primary Input Data*). Data layers can be sorted into separate folders under the *Primary* folder. The left hand side of the drop-down menu shows these folders. Layers can be brought into the display workspace by clicking and dragging them in from the right hand side of the menu with the mouse (figure 9).

FIGURE 9 Primary data icons for categorical and continuous Primary Input Data

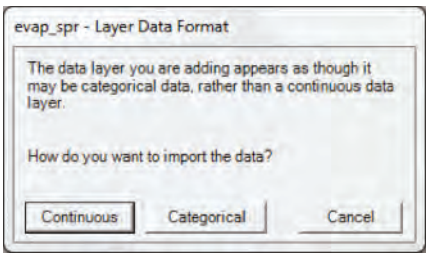


The two types of data usually included in the *Primary* folder are categorical data and continuous data (figure 9.) The *Primary* folder can also include time-series data. Each primary data layer type is identified by an icon in the *Primary* folder, differentiated by the presence or absence of a text (.txt) file with the same name as the data layer that provides labels for the categorical data classes.

5.1.1 Categorical data

Categorical data are grouped or categorised according to some common property, such as soil type or vegetation type. The data have labels that describe a category or group of interest. Although primary data grids contain only numerical values, labels describing categorical data can be displayed by including a text file with the same name as the grid file in the same data layer folder (see section 6.2.2 'Classifying categorical data'). When a categorical dataset with an associated text file is dragged into the workspace all categories from the text file will be initially assigned to the lowest class (dark blue). Assign classes to a different colour by clicking a category colour and then clicking the coloured box next to that category label. If there is no associated text file the *Layer Data Format* window will be generated (figure 10).

FIGURE 10 The Layer Data Format window


evap_spr - Layer Data Format
The data layer you are adding appears as though it may be categorical data, rather than a continuous data layer.
How do you want to import the data?
Continuous
Categorical
Cancel

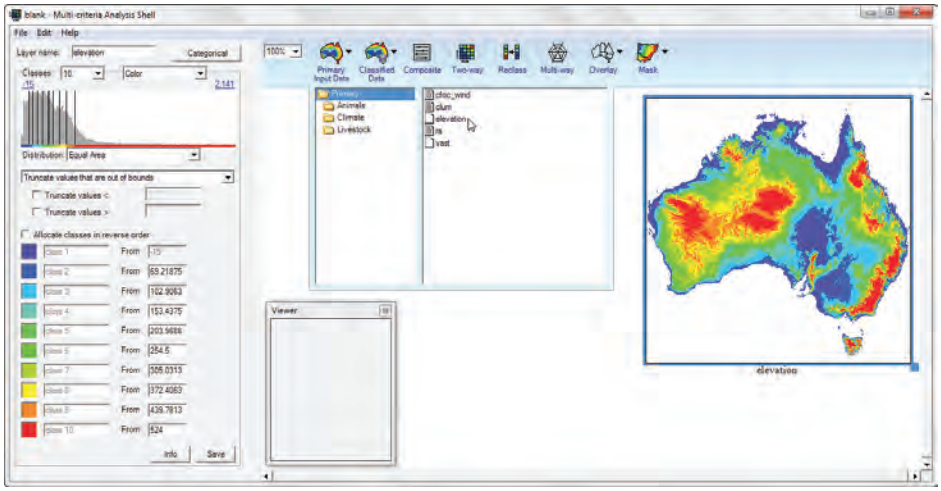
In the layer data format window select the *Categorical* option to assign classes manually. To enable MCAS-S to assign classes according to the order of the numerical values in the data layer, select the *Continuous* option. This window may also appear where continuous data has been rounded or certain values occur frequently.

5.1.2 Continuous data

In theory, continuous data may have an infinite number of possible values and are continuous in the geometry or range of values. In practice, the range of values for a particular item of data has a minimum and a maximum value, such as surface elevation and rainfall. Continuous data includes items such as densities, rates and percentages, which are classified according to project requirements.

Continuous data layers selected from the *Primary Input Data* menu will appear in the display workspace initially classified into five classes. The user can select from two to 10 classes. Figure 11 shows an example of the MCAS-S display workspace, with the drop-down menu for *Primary Input Data*, and the histogram and classification option for input data in the interface panel (discussed in section 6.2.1 'Classifying continuous data').

FIGURE 11 A Primary Input Data layer dragged into the display workspace



Note: The data layer elevation has been dragged from the *Primary Input Data* menu into the display workspace, allocated into 10 classes of equal area.

5.1.3 Time-series data

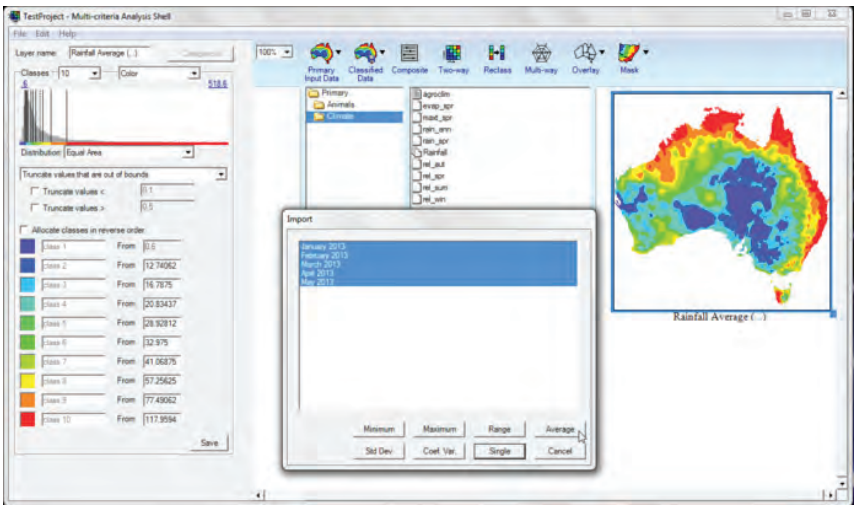
Expressions derived from continuous time-series data can also be imported into the MCAS-S display workspace. Time-series data can be identified by a stacked icon (for example, Rainfall) under the *Primary Input Data* menu (see figure 12). Selecting and dragging the icon into the display workspace will open an *Import* interface showing the list of gridded data layers available within the time series. A single data layer listed in the *Import* interface can be selected by clicking on the listed grid. Multiple data layers can be selected by clicking on a listed grid and holding down the shift key to select a group of grids, or the control key to select further individual grids for the group.

Clicking on a selected function button on the *Import* interface will derive a new layer expressing that function for the selected grids. The derived layer will appear in the MCAS-S display workspace.

A single grid is selected for inclusion as a layer in the display workspace by clicking on the listed grid and the *Single* function. Functions that can be applied to selected grids in the Import interface are as follows:

- *Minimum*—returns the minimum value for each cell from the selected grids
- *Maximum*—returns the maximum value for each cell from the selected grids
- *Range*—returns the difference between the maximum and minimum values for each cell (absolute variation) from the selected grids
- *Average*—returns the mean for each cell from the selected grids
- *Standard Deviation (Std Dev.)*—returns the standard deviation for each cell based on the selected grids
- *Coefficient of Variation (Coef. Var.)*—returns the coefficient of variation for each cell based on the selected grids.

FIGURE 12 Options for importing time-series data from the Primary Input Data menu



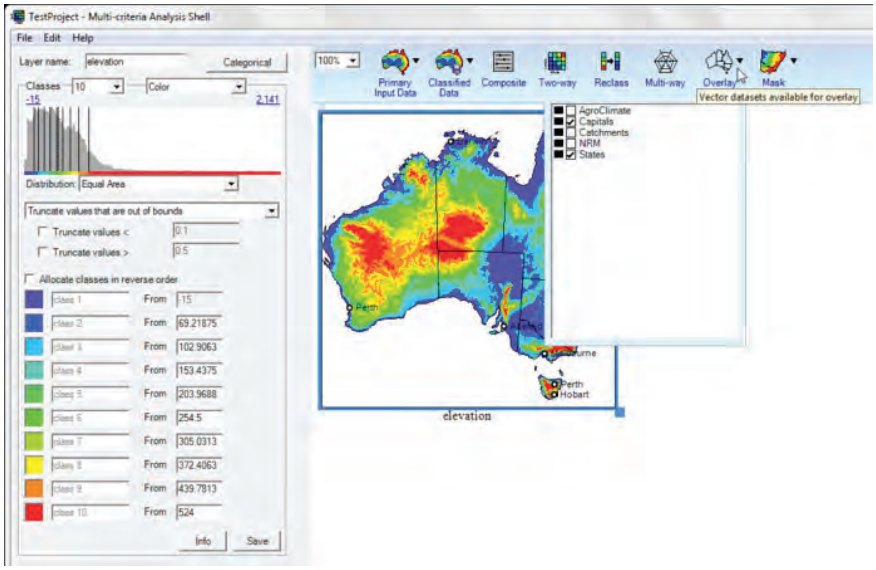
Note: Time-series data dragged from the *Primary Input Data* menu can be imported as individual datasets (Single option) or as a function of the selected datasets (Minimum, Maximum, Range, Average, Standard Deviation or Coefficient of Variation).

5.2 Overlay data

Overlays are lines or points (such as roads, towns and coastline) that can be added to a primary data layer to provide context. Overlays can be selected and displayed using the *Overlay* drop-down menu (figure 13). When overlays are selected, the default line or point colour is black. Colours can be changed by clicking on the colour box next to the overlay layer in the drop-down menu—this action brings up a colour palette from which a new colour can be selected. Differential colour selection is a useful function to distinguish multiple overlays.

Overlay layers can now be used in the analysis as a distance from points or lines. In order to create a layer from a point or line overlay to use in the analysis click and drag the overlay layer into the workspace. For more information see 'Distance from point or line overlays' (section 5.5.1.2).

FIGURE 13 Sample elevation data with point overlay data displaying capital cities and line overlay data displaying state boundaries



Adding an overlay will not change or affect the data or the results of a multi-criteria analysis, but will simply provide lines, borders and so on to assist interpretation of the map.

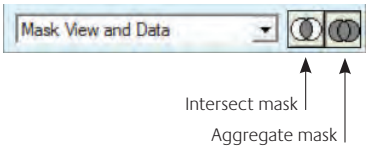
MCAS-S can display labelled points such as cities and towns. The number of points and labels displayed depends on the size and zoom level of the data layer being viewed. For example, at first only major cities may be visible, but as a user enlarges the window or selects a region mask, towns with smaller populations may become visible. To turn point labels on and off or modify other settings, see 'Preparing your own data' (section 5.5).

Overlay data are stored in the *\Data\Overlay* folder.

5.3 Mask data

Masks can be used to select specific areas for analysis and reporting. Using masks, it is possible to display only the data for a selected region (for example, a catchment or bioregion) within the map in the display workspace. Masks are introduced by expanding the *Mask* drop-down menu and clicking the box next to the regions required (see section 5.5 'Preparing your own data' for installing mask data layers). An aggregated mask can be created by checking one of the masks and holding down the shift key to select further masks. A mask formed from the intersection of two or more masks may also be created by clicking on the intersect symbol at the base of the *Mask* drop-down menu. The aggregated mask is similar to an OR function, showing pixels which occur in any of the regions selected, the intersection mask is similar to an AND function showing only the pixels which occur in both of the selected regions. The aggregate and intersect buttons are shown at figure 14.

FIGURE 14 Intersect and Aggregate Mask option buttons



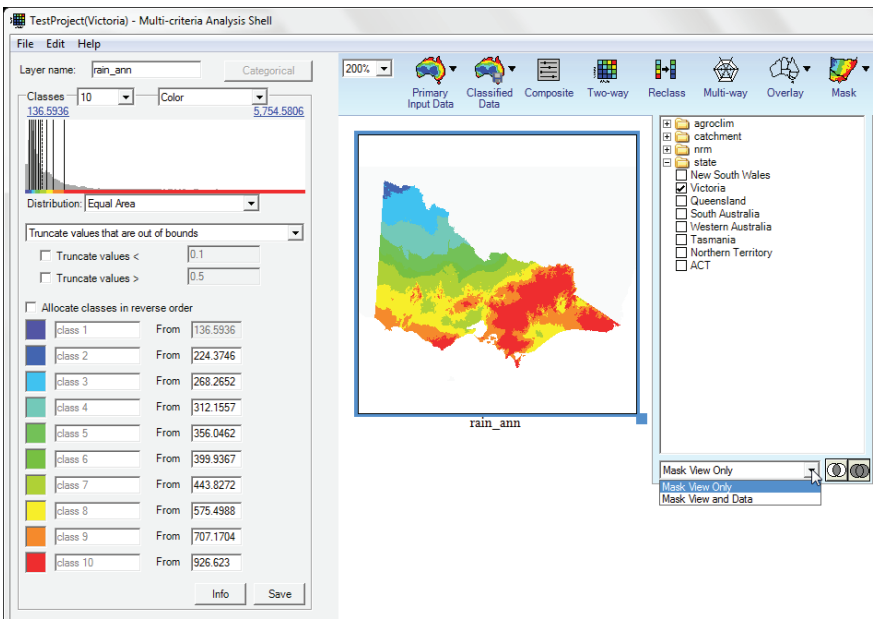
When masks are selected, masking applies to all functions and processes carried out in an MCAS-S project. A report can be created using any set of regions in the masks drop-down menu, even when an MCAS-S project is not masked. Reporting is covered in section 8.2.

Mask data are gridded raster data with an associated text file stored in the *\Data\Mask* folder (similar to primary categorical data). The user can choose to mask the view only or the data and view. This function is explained further in the next section.

5.3.1 Mask view only

When *Mask View Only* is selected from the drop-down menu in the *Mask interface panel*, each of the layers in the interface zoom to the region (or regions) selected (figure 15). The display and class allocation of the data themselves do not change as this mask option simply restricts the previous view to the region (or regions) chosen. Values shown in the histogram still refer to the full extent of the layer.

FIGURE 15 Annual rainfall data layer with a Victoria Mask View Only applied

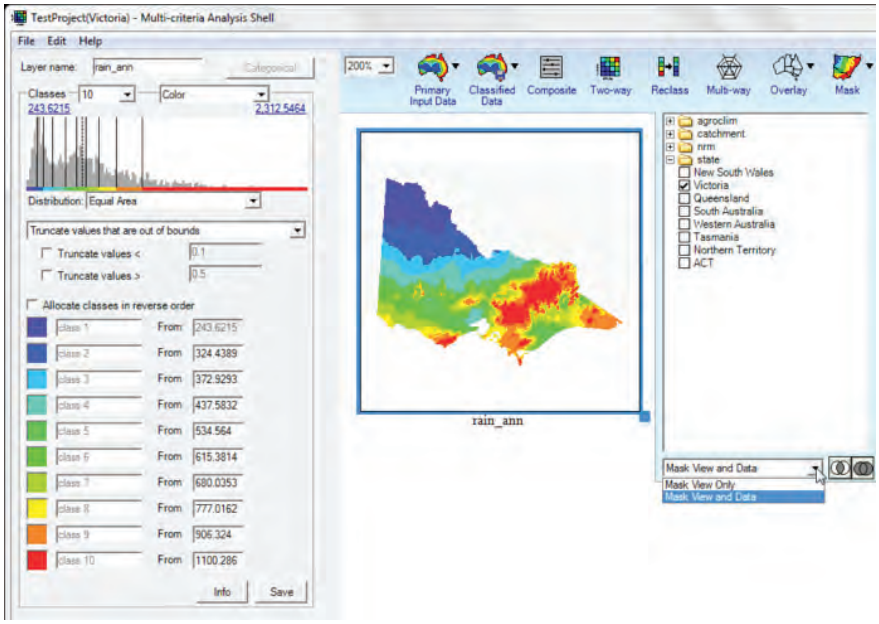


5.3.2 Mask view and data

Figure 16 illustrates the application of the *Mask View and Data* function. Only annual rainfall values specific to Victoria are displayed, and this is reflected by the changes in both the class allocation in the interface panel and in the display in the map window.

Previously, when mask view was selected, or a mask was not applied, the values in the classification ranged from 136.5936 to 5,754.5806 millimetres annual rainfall. However, the application of the *Mask View and Data* function (figure 16) changes these values to 243.6215 to 2,312.5464 millimetres annual rainfall as applicable to Victoria only and not to the whole of Australia.

FIGURE 16 Annual rainfall data layer with a Victoria Mask View and Data applied



5.4 Classified data

Classified data are layers that have been created by MCAS-S users from an MCAS-S analysis. Any data layer created or modified and exported as a new layer in MCAS-S will be saved into the *Classified data* folder. This includes *New User* layers (see section 5.6) and overlay distance layers (see section 5.5.1.2). Once created, these new layers can be added to a project by selecting and dragging them from the *Classified data* drop-down menu. Classified data layers can be created by exporting any of the MCAS-S analyses (two-way, multi-way, composite or user layer). More information on these functions is provided in section 6 'Explore and combine data'.

5.5 Preparing your own data

MCAS-S users may create projects using their own input data layers. Pre-processing using GIS software will usually be required to ensure data meet MCAS-S requirements, which are set out in this section.

When preparing data for use in MCAS-S, consider:

- what the data will be used for (primary input, overlay, or mask)
- how the data should be represented
  - categorical—which attribute will be used to create the class values
  - continuous—which numeric attribute value can be used, such as minimum, mean or maximum
- the appropriate spatial and temporal scales for the data.

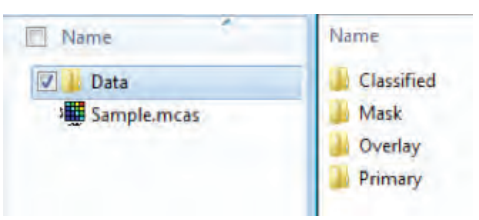
Data conversion documents for use with the GIS software programs ArcGIS 10 and ArcView 3.3 are available on the MCAS-S website, daff.gov.au/abares/data/mcass.

Input data for use in MCAS-S projects must conform to a common spatial-referencing system, (that is, a common projection). For example, the gridded data layers from the sample project and the Australian national map layers available on the MCAS-S website are in Albers Equal Area projection using the Geocentric Datum of Australia 1994 (commonly referred to as GDA94). Primary layers and mask layers must also have a common spatial extent or origin in order for MCAS-S to calculate correctly (that is, they must have common bounding boxes with the same north latitude, south latitude, east longitude and west longitude). For example, to prepare new data to use with the gridded data layers from the ready-to-use Australian national map layers available with MCAS-S version 3.1, match the extent of the new data with any of the ready-to-use layers in the *Primary* folder.

MCAS-S recognises and treats the value −9999 as 'no data' or missing values, and raster cells with these values are excluded from subsequent processes. This default setting may be switched off when creating composites.

The user's own MCAS-S spatial data inputs can be any of the types mentioned earlier, that is, primary input data (categorical, continuous or time-series), overlay data or mask data. The user's own data must be saved alongside the MCAS-S project in the Data folder structure shown at figure 17. The pre-processing phase of setting up an MCAS-S project is completed when spatial data inputs are located within the project file structure and are ready for use in MCAS-S drop-down menus under the headings *Primary Input Data*, *Overlay* and *Mask*.

FIGURE 17 The Data folder structure required for MCAS-S projects



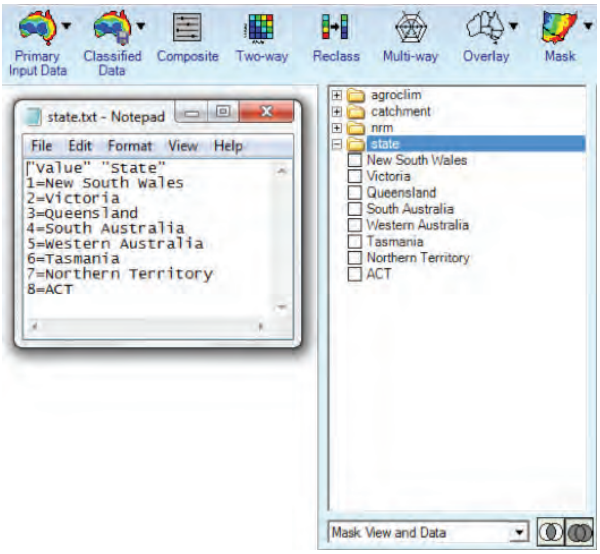
Note: The data folder must be saved alongside an MCAS-S project and contain the folders Primary, Classified, Mask and Overlay as shown.

5.5.1 Primary data

Primary data refers to raster data for analysis. GIS systems use two types of data—raster and vector. For raster data, representation of objects is based on the elements of a matrix, given as grids or pixels. For vector data, representation is based on distinct points described by their coordinates and relations.

Primary datasets can be in BIL, Arc GRID or GeoTIFF raster formats, and made ready for use within MCAS-S by saving the files in the project directory *\Data\Primary*. If the user has categorical data (that is, data expressed using classes such as states and territories) the data should be converted using a numeric code (for example 1 = New South Wales; 2 = Victoria etc) and these codes are translated to the categories using a text file with the same name as the raster (same structure as the *Mask* text file in figure 18). This text file should be saved in the same folder as the raster.

FIGURE 18 Mask data text file contents



5.5.1.1 Time-series data

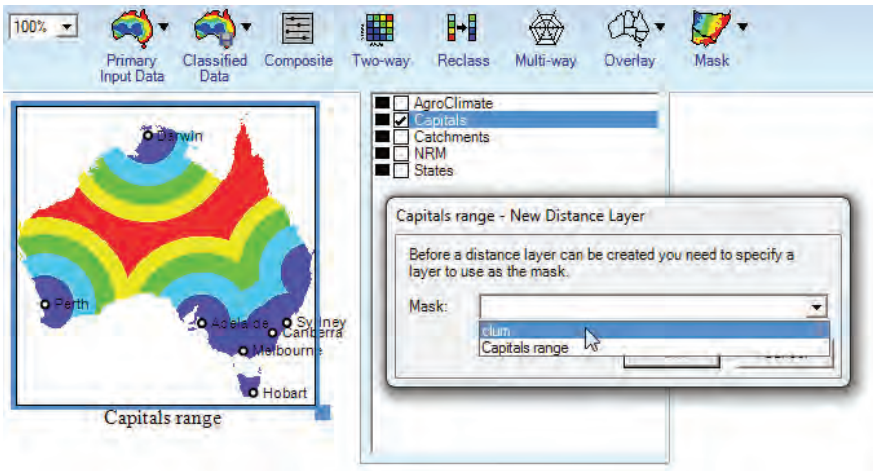
MCAS-S also recognises time-series data. These data should be stored as a stack of raster files in the appropriate format in a separate folder created within the *\Data\Primary* folder. There is some flexibility in naming the datasets in the time-series stack, but for MCAS-S to recognise the data as a time series, each component dataset needs to contain a string of either six digits or eight digits preceded by an underscore; six digits is assumed to be YYYYMM and eight digits is assumed to be YYYYMMDD. For example, 'rain_198001' would be a time slice of rainfall for January 1980 and 'rain_20051231' would be a time slice of rainfall for 31 December 2005. Note that once a name for a time series has been decided, each data point must have this prefix before the date.

5.5.1.2 Distance from point or line overlays

Overlay data is described in 5.5.2. In order to use overlay data in your MCAS-S project as an input layer rather than a contextual layer it must be converted to a raster. To create a raster of distance from the points or lines contained in an overlay layer, click on the overlay in the overlay menu, and drag the layer into the MCAS-S workspace. The *New distance layer* window will pop up requesting

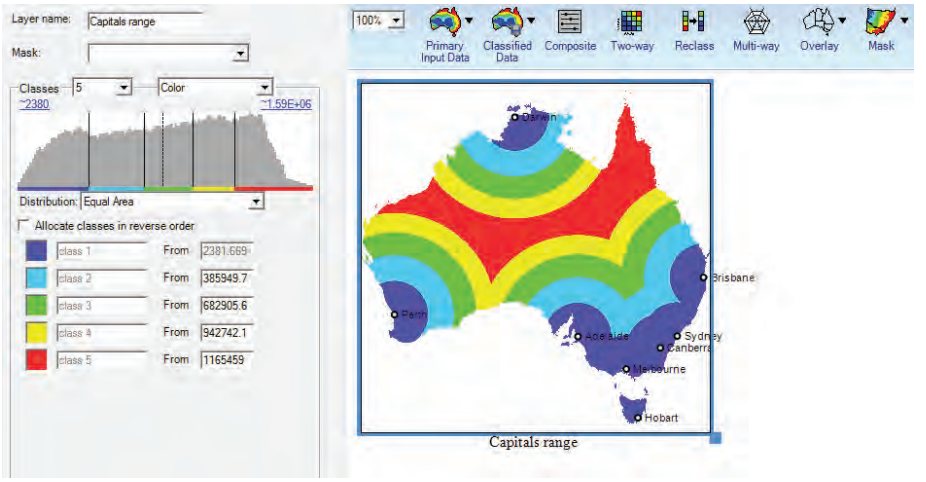
a mask to be selected (figure 19). The mask determines the cell size and included locations for the new layer. MCAS-S has now created a gridded data layer showing the Euclidian distance (based on number of pixels) of each cell to the overlay lines or points (figure 20). This layer can be exported, and saved in the classified data folder and used as a primary data layer in MCAS-S analysis.

FIGURE 19 New Distance Layer window



Note: When dragging in an overlay layer the user will be requested to choose a mask to set the cells size and any areas to be excluded from the new layer.

FIGURE 20 Distance to capital cities created from a point overlay



Note: The distance to capitals has been created by clicking and dragging the capitals point overlay into the workspace. This figure shows a distance to capital cities with a 1000 m x 1000 m resolution. The histogram on the left hand side interface panel shows the minimum and maximum number of pixels from a capital city.

5.5.2 Overlay data

Vector polygons, lines or point data for contextual overlays are optional. These datasets can be imported as ESRI shapefiles into the project directory *\Data\Overlay*. MCAS-S can display point data and labels. The user can specify whether labels will be displayed, and how many points will be displayed at a particular image zoom level, by adding a text file describing these conditions.

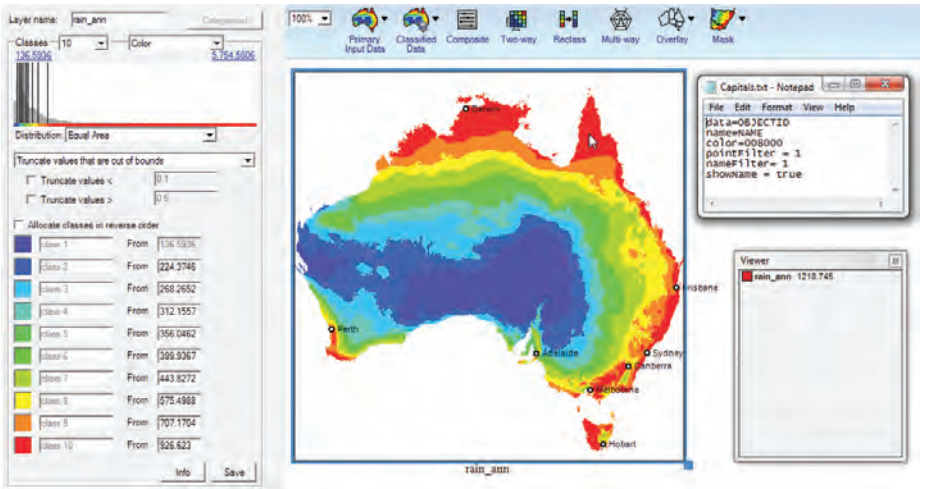
Each point file must be placed in individual folders in the overlay folder. The name of the individual folders will be displayed in the *Overlay* drop-down menu in MCAS-S. A text file with the same name as the folder is required to describe how the point file is to be displayed. This should be saved under *\Data\Overlay* rather than in the individual folder with the actual overlay dataset. To use new overlays with the layers supplied in the sample project, they will need to have the same projection (see section 5.5). The text file should contain:

- data = value field name (name of the field that contains the values that determine the order in which points will be displayed. This could be an existing field or may need to be created by the user with GIS software. Larger numbers will display first, with smaller numbers progressively displaying as the data layer is enlarged, so if a population field was chosen to control the display of cities, a city with 2 000 000 will display before a city with 100 000. When creating a new data display field, give higher values to points that are to display first)
- name = label field name (the field containing labels for the points)
- color = six digit hexadecimal code (e.g. 061D58 for dark blue)
- pointFilter = 1–1000+ (scale starting at 1 that controls the number of points displayed. If the number 1 is chosen, only the most important points [as determined by the data field] will be displayed. To display all points, choose a large number such as 1000. Note that depending on the number of points in the layer, the *pointFilter* value may need to be adjusted several times to display the desired number of points)
- nameFilter = 1–1000+ (similar to the *pointFilter*, this is a scale that controls the number of labels displayed. If the number 1 is chosen, only a small number of labels will be displayed. To display all labels, choose a large number such as 1000 [this may need to be larger depending on the number of points]. It may be advisable to set the *nameFilter* lower than the *pointFilter* so labels do not become too crowded)
- showName = true (labels display) or false (labels do not display).

Note that some of the above settings may be overridden depending on the sizes of layers in the MCAS-S workspace. If some points appear to be missing, try maximising the size of layers to ensure desired points and/or labels are displayed. If this does not work, the *pointFilter* and *nameFilter* settings may need to be increased.

An example of a text file for a point dataset is shown in figure 21.

FIGURE 21 Example of text file information for point overlay data



Note: In this example, the field containing the data for displaying the points is called 'OBJECTID', the label field is 'NAME', the filter for displaying points and labels is 1 (fewer points and labels will display as the layer is minimised) and the display of labels is turned on ('true').

5.5.3 Mask data

Mask data refers to raster data that define the geographic limits for analysis and reporting (optional). All cells of interest have a value and, by using particular masks, only the information within the area of interest will be considered in the analysis and displayed. These datasets can be imported in BIL, Arc GRID or GeoTIFF raster formats by saving them in the project directory *\Data\Mask*.

To use mask data layers in MCAS-S the grid values must be labelled. This is done by including text files with the same name as the mask files in the *Mask* data folder. The labels within the text file will be displayed in the *Mask* drop-down menu on the MCAS-S interface (figure 18). The left window in figure 18 shows the state mask with labels and grid values from the state text file. The right window shows the corresponding list of states from the *Mask* drop-down menu on the MCAS-S display workspace.

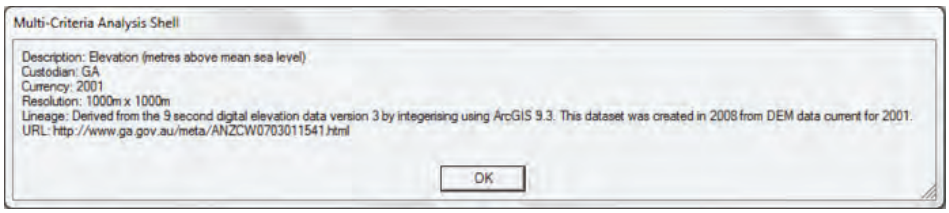
5.5.4 Metadata files

Metadata files, which are called tip files in MCAS-S, should be created for each new layer added to MCAS-S. Tip (.tip) files contain extra information about the data layer to ensure that the layer is used and interpreted correctly (figure 22). Tip files can be created and edited using Wordpad by copying the structure of an existing .tip file. The text should be specific for the dataset. Tip files should be saved beside primary data layers with the same name as the primary data layer. Tip file information includes:

- dataset name—shortened version to display when mouse hovers over it
- description—more information on the data, including units if applicable
- custodian—organisation that owns the data

- currency—year (for example, 2006)
- resolution—grid size of the raster data; layers in the sample project have been provided at a resolution of 1000 m x 1000 m
- lineage—processing completed on the data (for example, source, calculations, software/commands used)
- URL—a website where more detailed metadata may be found.

FIGURE 22 Example of tip file information displayed when accessed through MCAS-S


Multi-Criteria Analysis Shell
Description: Elevation (metres above mean sea level)
Custodian: GA
Currency: 2001
Resolution: 1000m x 1000m
Lineage: Derived from the 9 second digital elevation data version 3 by integerising using ArcGIS 9.3. This dataset was created in 2008 from DEM data current for 2001.
URL: http://www.ga.gov.au/meta/ANZCW0703011541.html
OK

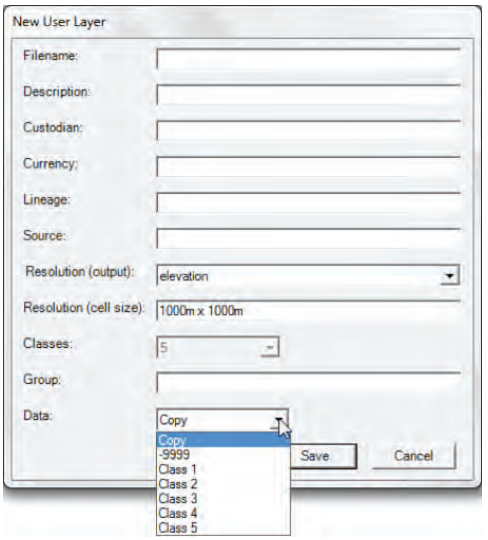
Note: The information in the .tip files for a selected primary input data layer is accessed by clicking the Info button on the left hand interface panel.

5.6 Creating user layers

It is possible for the user to create their own layers in MCAS-S by editing any layer in an MCAS-S project display workspace (except multi-way layers). Creating user layers is a way of capturing expert knowledge where other data may be incomplete or unsatisfactory, and incorporating this knowledge into an MCAS-S project.

Layers can be created from scratch, with only the boundary of an existing layer used, or edits can be made to an existing layer. To create a user layer, right-click on a layer in the display workspace and select *New User Layer*. A dialogue box will then appear. Fill the spaces to give the new layer a filename, set the resolution to an existing layer, fill in other metadata and then save the new layer to a group (folder) under *Classified Data* (see figure 23). The number of classes will be the same as the existing layer and cannot be changed. Under the *Data* drop-down menu, there is the option to simply copy the existing layer, set the layer to −9999 (no data ready for editing) or set the layer to one of the existing classes (creating a layer of pixels with a default value).

FIGURE 23 New User Layer settings window displaying the options for which data to copy across from the previous data layer



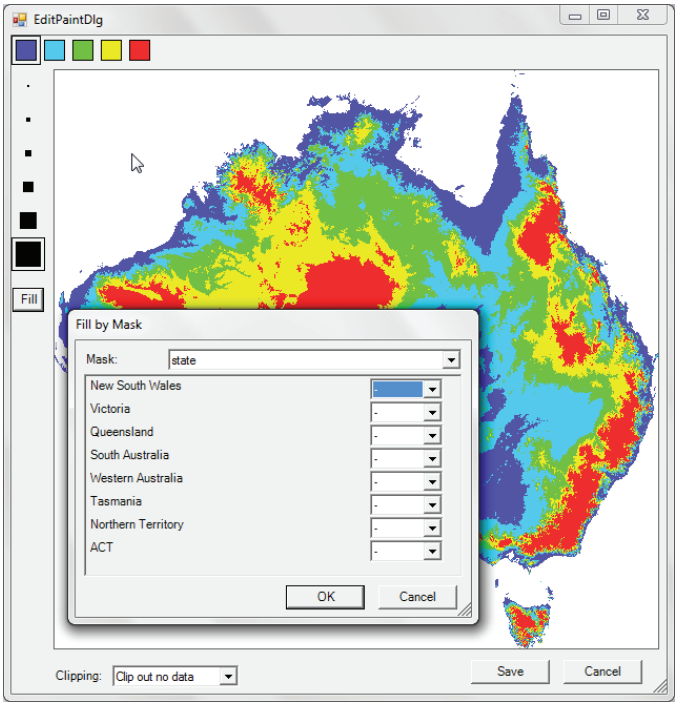
Once preferences have been saved, the new layer will appear in the display workspace (the preferences are also saved under *Classified Data*). To view the metadata information, click on the *Info* button on the interface panel. To edit the layer, click on the *Edit* button in the interface panel, which will open a window as shown in figure 24. To 'paint' areas of the layer, select a 'brush' size using one of the black squares to the left of the layer, and select a class colour from the options at the top of the layer. These colours refer to the classes in the original layer. Areas on the map can be edited by either left-clicking or clicking and dragging to edit larger areas. To colour areas based on regions, click the *Fill* button, choose a *Mask* region and assign class numbers to one or more of the regions using the drop-down menus (for an example edited using 'painting' and the fill option, see figure 25).

Below the layer display in the editing window, one of the following three options for clipping the data can be selected:

- *no clipping*—does not clip to the extent of the dataset and therefore colour may be applied anywhere within the editing window
- *clip out no data*—this option is the default setting; only areas with a class value or set to −9999 are available for editing ('no data' areas are unavailable for editing)
- *clip to −9999*—only areas set to −9999 can be edited.

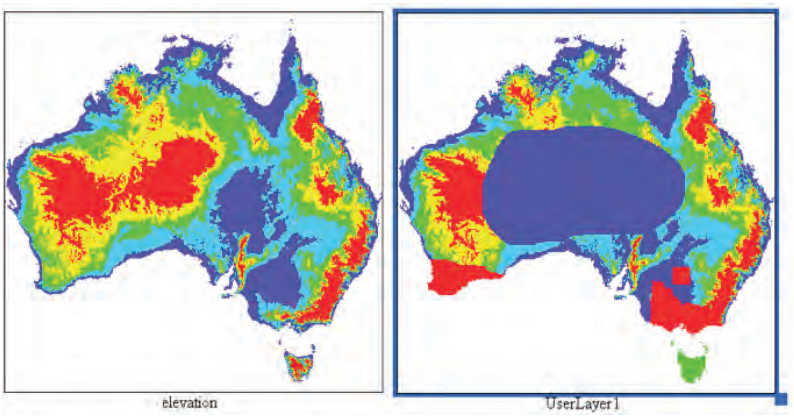
Edits can be saved by clicking the *Save* button. In order to undo any edits, click the *Cancel* button. Note that clicking the *Cancel* button will erase all unsaved changes made during the editing session.

FIGURE 24 A New User Layer based on elevation open for editing



Note: Editing can be completed using the paint functions or by filling whole mask regions with a value (as shown in the open *Fill by Mask* window).

FIGURE 25 Edits have been made to a user layer using the paint and fill tools

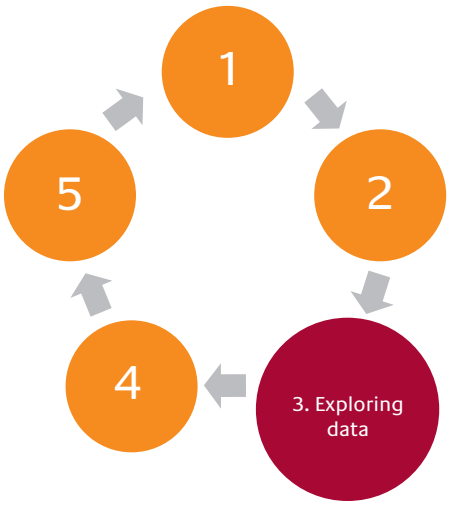


Note: Edits have been made to central Australia (blue), parts of Western Australia and New South Wales (red in south-west WA and red square in western NSW) using the paint functions, and Victoria and Tasmania have been reassigned values for the whole state using the Fill tool (as can be seen when compared to the original layer)

This section has outlined how to assemble data and how to bring data layers into the MCAS-S display workspace, ready for use. The next section outlines how these data layers can be classified, compared and combined to explore the data.

6 STEP 3: EXPLORE AND COMBINE DATA

Primary data layers are compared and combined in MCAS-S by assigning raw data into classes and working with these classes. Some raw data contain continuous numerical values while others have been grouped into categories where the labels and not the numbers are of interest. This section describes how to set up the MCAS-S workspace, classify data, and explore simple relationships between data layers.



6.1 Setting up the MCAS-S workspace

6.1.1 Moving data layers

To move a single layer: click on the layer so that it shows as the active layer (by the dark blue border) and drag this layer to a new location. To move multiple layers while maintaining their relative location hold down the shift key and click on layers of interest, again the blue border will show. Once layers are selected click and drag to the new location using the mouse. Once multiple layers are selected it is also possible to realign the selected layers to top, bottom, left, or right by selecting these options on the left hand panel.

To move around the workspace use the slider bars at the bottom and right hand side of the workspace, or hold and press the spacebar while clicking and dragging somewhere on the workspace.

6.1.2 Resize data layers

To resize a single data layer: click on the layer (the blue border shows that the layer is active), click the bottom right hand corner of the layer with the mouse and expand to the desired size.

Multiple layers can be resized at the same time by holding the shift key while selecting the layers of interest with the left mouse button and selecting 'resize to smallest' or 'resize to largest' from the resizing options on the left hand side of the screen.

6.1.3 Delete layers

The *Delete* function can be accessed by right-clicking on any layer. This function removes the active map window from the display workspace. Delete multiple layers at the same time by clicking on the layers to be deleted while holding down the shift key then right clicking and selecting delete. Deleting a layer from the workspace will not delete the underlying data. The layer can be added back into the workspace but the classification of the data may be lost.

6.1.4 Zoom options

Zoom options are listed below:

- To zoom in on a single map layer, double click anywhere in the layer. Press Esc to return to normal view.
- To zoom in on the display workspace, hold the control key and click anywhere in the workspace, or select a larger magnification (such as 200%) from the zoom drop-down list in the left corner of the MCAS-S functions toolbar.
- To zoom out, hold the control and shift keys and click anywhere in the workspace, or select a smaller magnification (such as 50%) from the zoom drop-down list in the left corner of the MCAS-S functions toolbar.

6.2 Classifying data

Continuous and categorical data are classified differently, as described below. Once a primary data layer has been classified, the user is able to save settings for that layer, even if it is subsequently deleted from the project. Note that saving the class settings makes them the default display settings for that layer in the current project and all future projects.

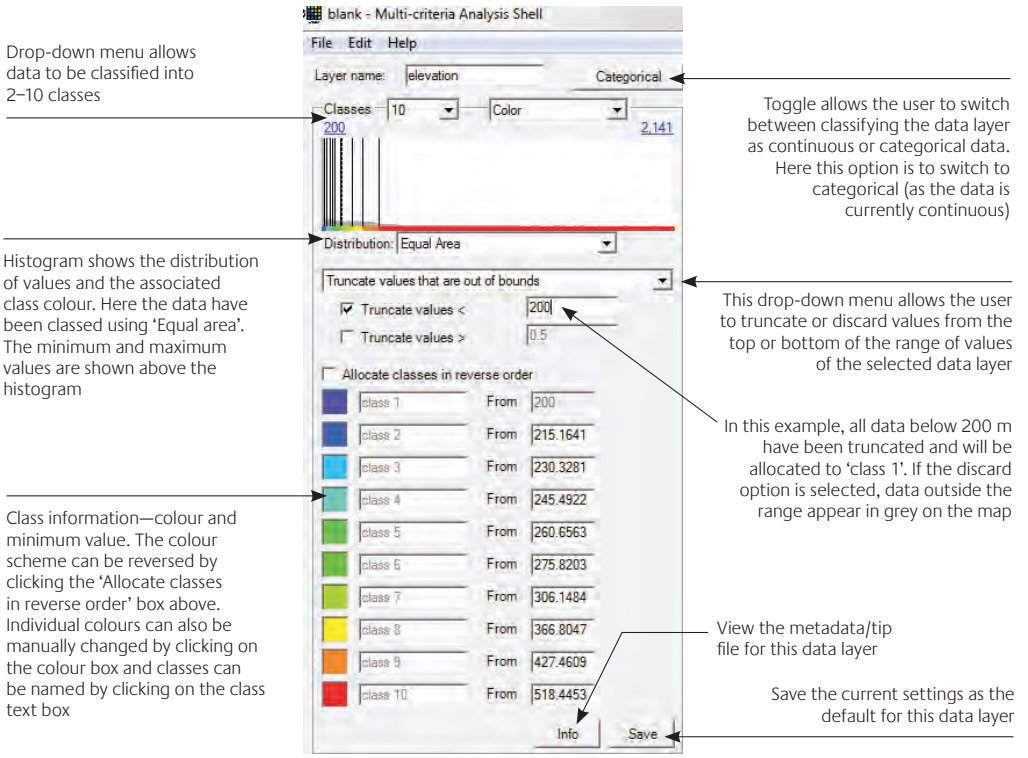
When classifying data, it is important to use the same classification system for all data. For example, are all of the data being classified from 'suitable' to 'not suitable', or from 'high' to 'low', or from 'good' to 'poor', in terms of the objective? If so, colours can be assigned accordingly so that, for example, blue classes always denote 'not suitable' and red classes always denote 'suitable'. This consistency will ensure that input layers are compared and combined using the same classification system. In the example 'Location of soils at risk' all inputs will be classified from low to high risk of degradation.

Almost all of the classification options in MCAS-S assume that the data is arranged in such a way that 'suitable' occurs at one end of the scale of values, while 'not suitable' occurs at the other end. Sometimes this is not applicable to your objective as a moderate value may be the most suitable value with extreme values being less suitable, or data has previously been classified to meet another objective. The reclass tool described in 6.2.3 allows more flexibility in assigning classes to the most appropriate order for analysis.

6.2.1 Classifying continuous data

Once dragged into the MCAS-S interface, each primary data layer can be classified into up to 10 classes using an *Equal interval*, *Equal area*, *Log*, *Standard Deviation*, *Natural Breaks* or *Custom* (user-defined) classification under the *Distribution* drop-down menu. Classifying the data according to *Equal interval* groups the data into regular classes regardless of their distribution. *Equal area* allocates the same number of data points to each class (figure 26). Log allocates classes in a logarithmic scale by value. *Standard deviation* assigns values based on deviation from the mean. *Natural breaks* assigns classes based on clusters of values.

FIGURE 26 The continuous Primary Input Data interface panel on the left of the MCAS-S display workspace


Drop-down menu allows data to be classified into 2–10 classes
Histogram shows the distribution of values and the associated class colour. Here the data have been classed using 'Equal area'. The minimum and maximum values are shown above the histogram
Class information—colour and minimum value. The colour scheme can be reversed by clicking the 'Allocate classes in reverse order' box above. Individual colours can also be manually changed by clicking on the colour box and classes can be named by clicking on the class text box
blank - Multi-criteria Analysis Shell
File Edit Help
Layer name: elevation
Categorical
Classes 10
Color
200
2,141
Distribution: Equal Area
Truncate values that are out of bounds
Truncate values < 200
Truncate values > 0.5
Allocate classes in reverse order
class 1 From 200
class 2 From 215.1641
class 3 From 230.3281
class 4 From 245.4922
class 5 From 260.6563
class 6 From 275.8203
class 7 From 306.1484
class 8 From 366.8047
class 9 From 427.4609
class 10 From 518.4453
Info
Save
Toggle allows the user to switch between classifying the data layer as continuous or categorical data. Here this option is to switch to categorical (as the data is currently continuous)
This drop-down menu allows the user to truncate or discard values from the top or bottom of the range of values of the selected data layer
In this example, all data below 200 m have been truncated and will be allocated to 'class 1'. If the discard option is selected, data outside the range appear in grey on the map
View the metadata/tip file for this data layer
Save the current settings as the default for this data layer

The *Log* option works as follows: given a set of values from x0 to x1, the range of the values is x1 minus x0. To find a log classification for n classes, MCAS-S determines the *n*th root of the range and uses this value as the base of the log. For example, a set of values from 0 to 1000 has a range of 1000 (1000 minus 0). If it were classified into three classes, the cube root would be 10, leading to splits of 10 and 100. If it were split into five classes, the fifth root would be ~3.98107, leading to splits of ~3.98, ~15.85, ~83.096 and ~251.19.

The *Standard deviation* option works as follows: the mean value is calculated and displayed as a broken line on the histogram; the classes are defined by deviation from the mean. If four classes are selected these will be: class 1 (lowest value to one standard deviation below the mean), class 2 (one standard deviation below the mean to the mean), class 3 (mean to one standard deviation above the mean), class 4 (one standard deviation above the mean to the maximum value). The standard deviation relating to each class is shown on the right hand side of each class in the interface panel.

The *Natural breaks* option works as follows: class values are identified based on grouping similar values to emphasise differences between classes. The classification is based on the Jenks' natural breaks algorithm. Allocation to classes is made to minimise the sum of squared deviation from the mean for each class.

The *Custom* option allows the user to set the specifications for data classification, for example, to specify threshold values for each class. The values can be set by sliding each vertical boundary on the histogram to the desired value, thereby changing both the map colours and the corresponding

value in the classification box. Alternatively, the values can be manually entered into the classification boxes.

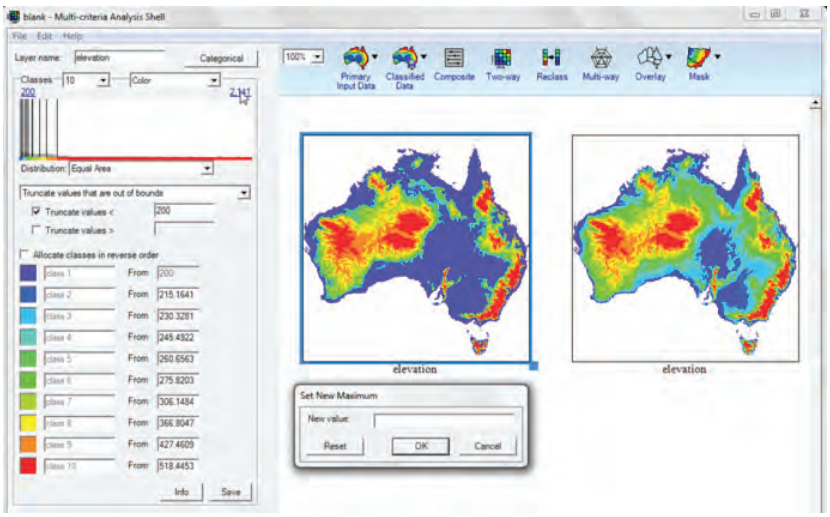
Default class names (for example, 'class 1' or 'class 2') can be changed by typing into the text boxes.

For more information on of the input layer, click on the *Info* button to bring up its metadata. This will give information such as source, units and currency, which will help with classification. If the *Info* button is not displayed, then there is no metadata (.tip file) for the layer.

The values can be truncated from the bottom of the range by selecting *Truncate values that are out of bounds* in the drop-down menu, checking the box *Truncate values* <, and assigning a value below which values will be included in the lowest class. Values can also be truncated from the top of the range by checking the box *Truncate values* >, and assigning a value above which values will be included in the highest class. This facility allows the user to manage the range of classified values, particularly outlier values or highly skewed distributions.

In figure 27, the user has chosen to truncate elevation values < 200. The 10-class *Equal area* classification has been applied to the elevation range 200–2,141 m. Values below 200 m have been allocated to class 1, which therefore includes all values < 215.1641 m. The original data, which has not been truncated, is shown on the right hand side map.

FIGURE 27 Using the Truncate values tool



Note: The elevation data layer has been classified into 10 classes using the *Equal area* option. In the left hand data layer a lower range limit of 200 m has been applied; this means that all values (heights) less than 200 m have been allocated to class 1 (< 215.1641 m displayed in blue). The same data layer without the lower range limit applied is shown for comparison. The break points of some classes change when using equal area classification with the new truncated range.

The minimum and maximum values of the range (of complete or truncated values) for the selected data layer are displayed above the histogram. This feature can be useful when deciding where to make breaks using the *Custom* option.

Values can also be removed from both the top and bottom of the range by selecting *Discard values that are out of bounds* from the same drop-down menu, and again assigning a minimum

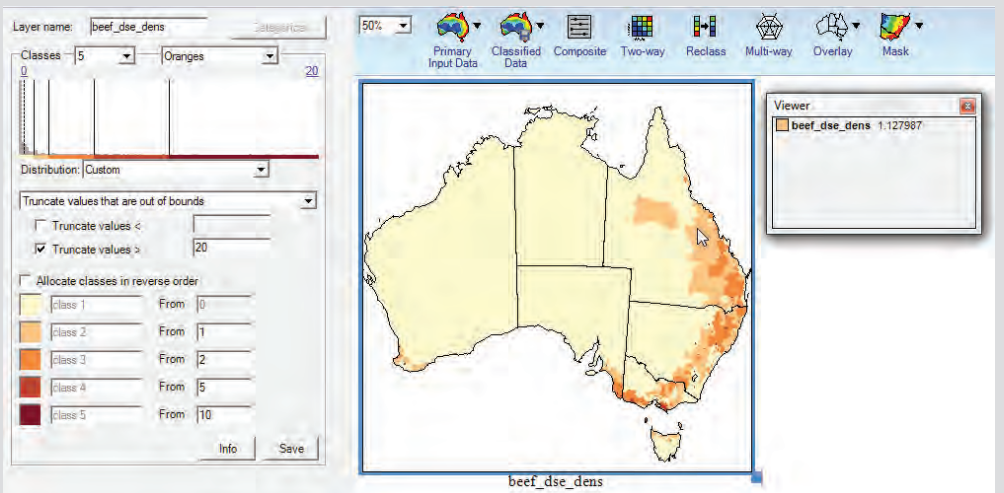
and/or maximum value. Areas with values outside the selection will appear as light grey in the corresponding map window.

Minimum and maximum values can be set to user-defined limits by clicking on either value in blue above the histogram and entering the desired value in a dialogue box (figure 27). To restore the original minimum and maximum values, select the value in blue above the histogram again and click the *Reset* button.

BOX 3 Hypothetical location of soils at risk—classifying continuous data

For cattle grazing, in each statistical area (SA2) for Australia, stock densities (dry sheep equivalents per hectare) have been truncated so that any values above 20 are allocated to the highest class. The remaining values have subsequently been allocated into 10 classes, from low cattle grazing density (pale yellow; least at risk) to high cattle grazing density (dark red/brown; most at risk) using an *Equal Area* classification.

The viewer displays the raw value for the area that the mouse is hovering over.



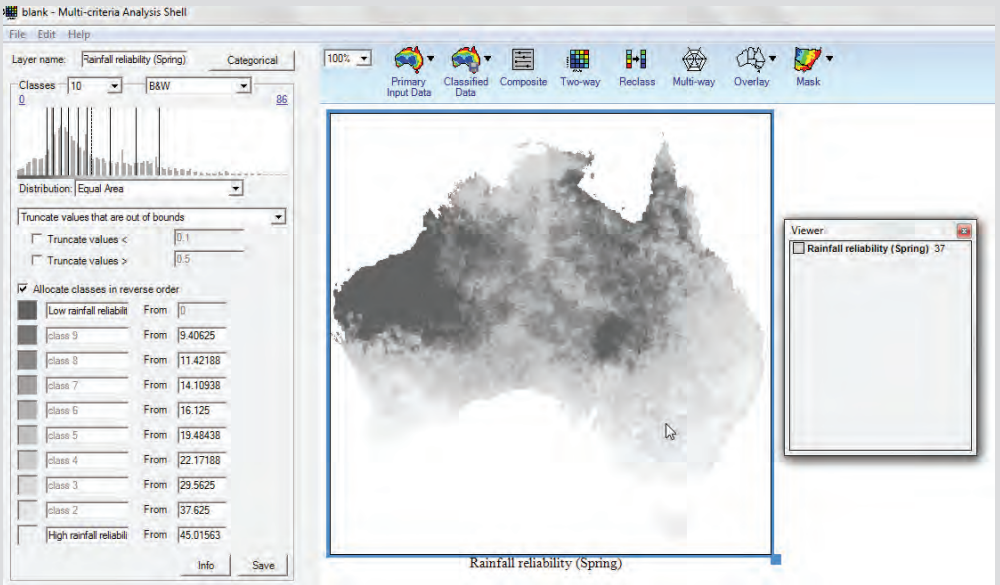
The final option in the continuous *Primary Input Data* interface panel is an *Allocate classes in reverse order* check box, which simply reverses the order of the class colours. This option may need to be used when the values of one of the input layers are different to others. For example, high values for a number of the input layers may be 'suitable' in terms of the overall question (such as high erosion in the 'location of soils at risk' example) whereas low values may be 'suitable' in another layer (such as low rainfall reliability). Reversing class allocation means that layers can then be classified using the same colour scheme.

Time-series data should be classified in the same way as continuous data.

BOX 4 Hypothetical location of soils at risk—allocating classes in reverse order

For the data layer 'Rainfall reliability', classes have been allocated in reverse order because areas with a lower rainfall reliability (black) will be more complex to manage and so more 'at risk' than areas with a reliable rainfall (light grey).

The viewer displays the raw value for the area that the mouse is hovering over (as a percentage of years where at least 50 per cent of expected spring rainfall has fallen).



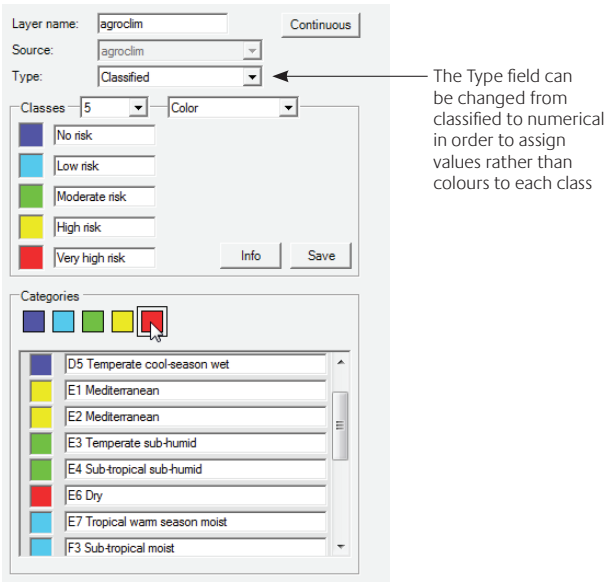
6.2.2 Classifying categorical data

Categorical data can be classified using the categorical *Primary Input Data* interface panel to suit project requirements. Two methods are available for classifying categorical data. First, the *Classified* option allows users to develop class groups, usually 'high' through to 'low' or 'good' through to 'poor', from input attributes. Second, the *Numerical* option allows users to assign numerical values to input attributes. The desired option should be selected from the *Type* drop-down menu (figure 28).

To better understand the input layer, click on the *Info* button to bring up its metadata. This will give information such as source, categories and currency, which will help with classification. If the *Info* button is not displayed, then there is no metadata (.tip file) for the layer.

The *Classified* categorical *Primary Input Data* interface panel displays the classes (up to 10) as well as the categories that make up the *Primary Input Data* layer (figure 28). Default class names (such as 'category 0', 'category 1' or 'category 2') can be changed by typing in the text boxes. The program will default to five classes. If necessary, the user can reselect the number of classes required.

FIGURE 28 Detail of the Classified categorical Primary Input Data interface panel



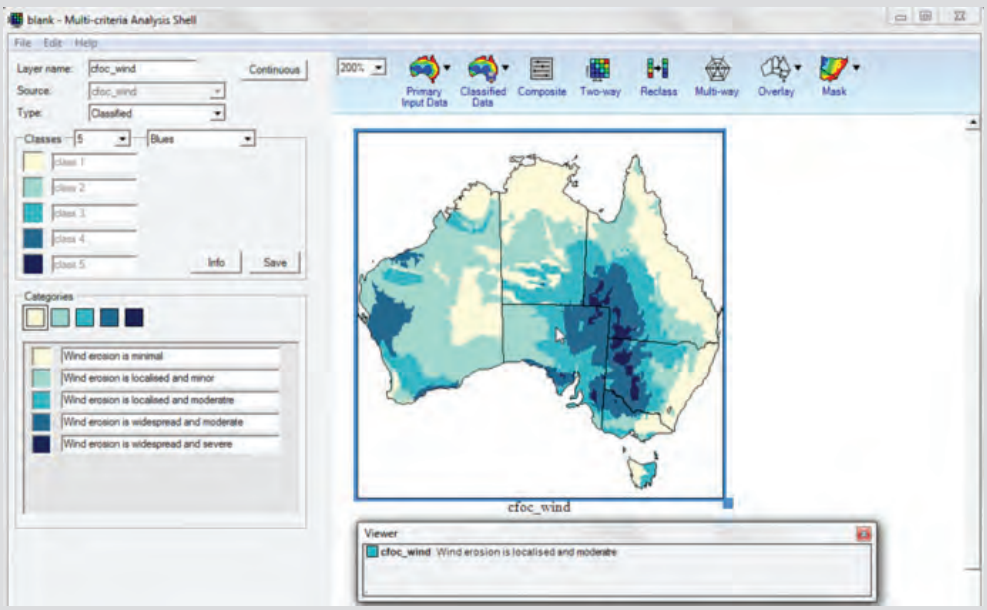
Note: the Classified categorical *Primary Input Data* interface panel with a primary data layer of agroclimate regions classified to show the estimated risk of soil erosion by wind.

The user can specify how categories are grouped together (for example, 'high risk' through to 'low risk') and manually types these groups into the *Classes* area of the interface panel. Classes are allocated by first clicking on the appropriate colour box in the *Categories* area of the interface panel, then by clicking the corresponding box next to the category of interest. For example, in figure 28 E6 Dry is allocated to a red category assigning it to the 'Very high risk' class.

BOX 5 Hypothetical location of soils at risk—classifying categorical data

In 2009, an analysis was undertaken on behalf of the Australian Government Caring for our Country program to determine the extent and severity of wind erosion across Australia (BRS 2009). The continent was split into five classes, ranging from minimal wind erosion to widespread and severe wind erosion. The layer has been assigned colours so that pale yellow shows the least risk to soils and dark blue shows the greatest risk to soils.

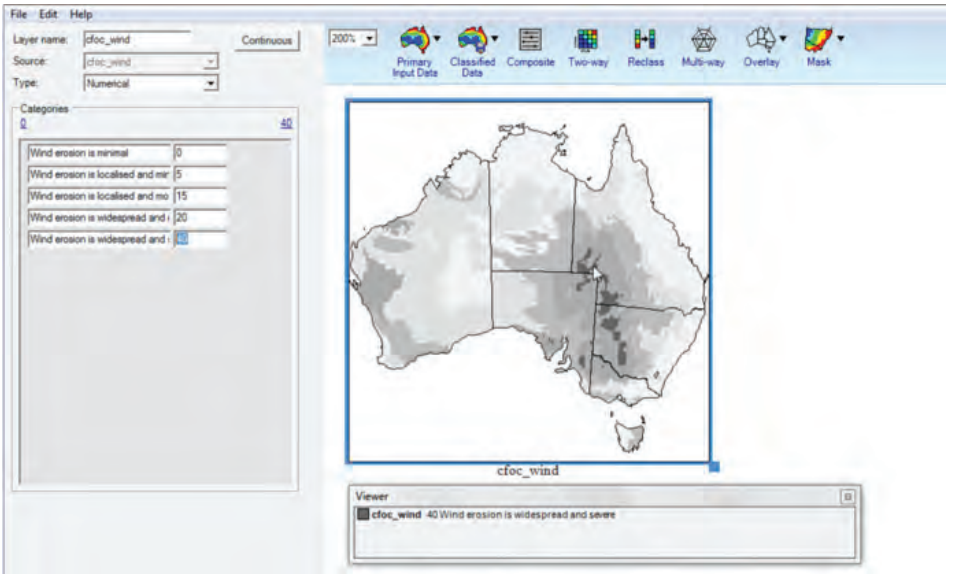
The viewer displays the class value for the area that the mouse is hovering over. The extent and severity of wind erosion is one of the primary data inputs for the 'soils at risk' example.



The *Numerical* categorical *Primary Input Data* interface panel displays categories in the primary data layer and allows the user to enter a numerical value against each category (figure 29). The layer is then scaled based on the minimum and maximum values entered using a greyscale. The scaling range can be changed by clicking on a blue value under *Categories* and entering a new value. To restore the original minimum and maximum values, select the values again and click the *Reset* button.

Clicking on the top right button in the panel (*Continuous*) of either categorical classification interface changes the categorical classification to continuous, and automatically allocates classes.

FIGURE 29 Detail of the Numerical categorical Primary Input Data interface panel



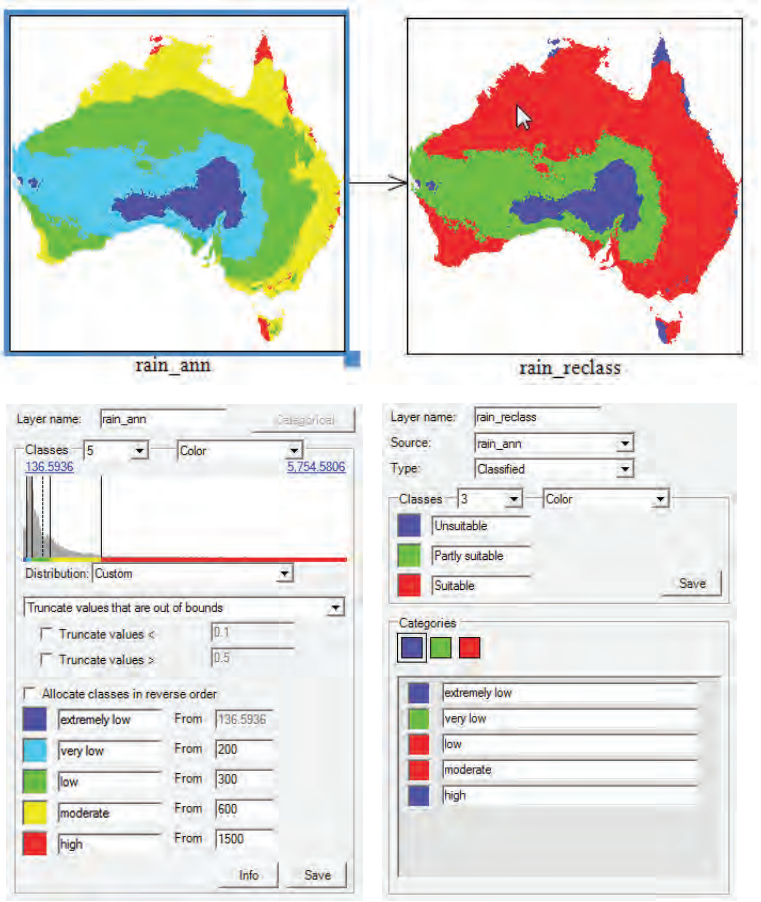
Note: The *Numerical* categorical *Primary Input Data* interface panel is shown with a primary data layer of wind erosion extent and severity assigned numerical class values from 0 to 40.

6.2.3 Reclassifying data to a new order

The *Reclass* tool allows classes from primary data layers to be reclassified in a new order more applicable to a particular MCAS-S analysis. This is useful where the data is not arranged such that 'suitable' and 'not suitable' occur at either end of the scale of values. In some cases a moderate value is the most suitable value with extreme values being less suitable or the data has previously been classified to meet another objective.

Click and drag a *Reclass* layer from the MCAS-S toolbar into the workspace. Set your input data layer (the layer from which the data values or classes will be taken). Assign the new order of classes appropriate for the analysis. Figure 30 shows a reclass layer where moderate annual rainfall is preferred. In this example extremely low rainfall (below 200 mm) and high rainfall (above 1500 mm) have be assigned to the unsuitable (blue) class and low to moderate annual rainfall (300 mm to 1500 mm) have be assigned to the suitable (red) class. This new classification can then be included in further analysis.

FIGURE 30 Reclass tool used to assign importance to values in the middle of the range



Note: This example shows annual rainfall reclassified to select areas of moderate rainfall 300–1500 mm into the highest class (red).

6.3 Comparing data

The spatial relationship between data layers may be examined using several methods in MCAS-S. This section discusses comparing and exploring data using *Two-ways*, *Multi-ways* and *Underlays*. Section 6.4 discusses combining data layers using composite functions. A summary of methods that can be used to compare and combine data and when they may be appropriate is shown at table 1.

6.3.1 Two-way comparison

A two-way comparison allows the user to explore the spatial association between two data layers. It also allows the user to define a colour ramp and value scale to highlight the association of high and low values of the contributing layers. Clicking on the *Two-way* menu button and dragging a new map window into the display workspace brings up the two-way interface panel at the left (figure 31).

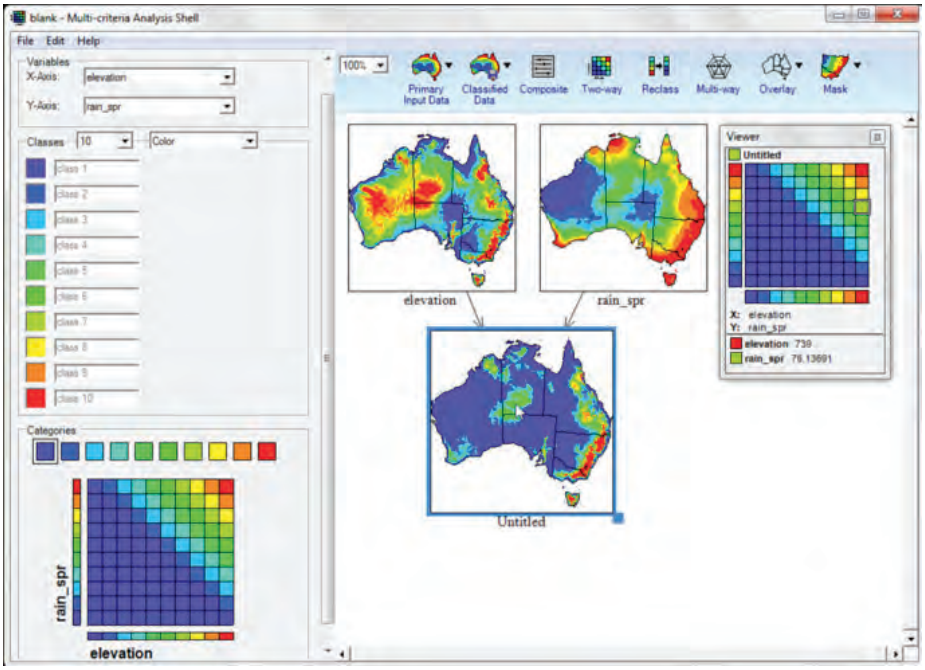
TABLE 1 Comparison of methods to compare or combine data layers in MCAS-S

	Two-way	Multi-way				Composite			Sensitivity Analysis (only for manual composite)
		Mask	Coincidence count	Composite	Underlay	Manual	Function	AHP	
More than two input layers		✓	✓	✓		✓	✓	✓	
New output layer	✓	✓	✓	✓		✓	✓	✓	If chosen
Rapid assessment	✓	✓	✓	✓	✓	✓			✓
Check for correlation[1]	✓								
Compare a layer with all other open layers					✓				
Use raw values						✓	✓		✓
Specify weightings						✓	✓	✓	
Test weights									✓
Inputs have equal weight		✓	✓	✓		✓	✓		
Inputs have different weight						✓	✓	✓	
Integer weights						✓	✓	✓	✓
Non-integer weights							✓		
Classes do not align[2]	✓				✓		✓		
All inputs combined using same function						✓		✓	
Inputs combined using different functions							✓		
Binary output required	✓	✓					✓		
Non-binary output required			✓	✓		✓	✓	✓	✓

[1] Correlation between two layers can also be investigated using a correlation report (section 8.2.3)

[2] In general all primary inputs for MCAS-S analysis should be classified according to the project objective (for example from high to low or suitable to unsuitable). Some methods listed in the table can still be used when the inputs classifications are not aligned. In order to use functions which have not been selected in this row use the *Reclass* tool to classify inputs according to the project objective.

FIGURE 31 Two-way analysis between elevation and rainfall



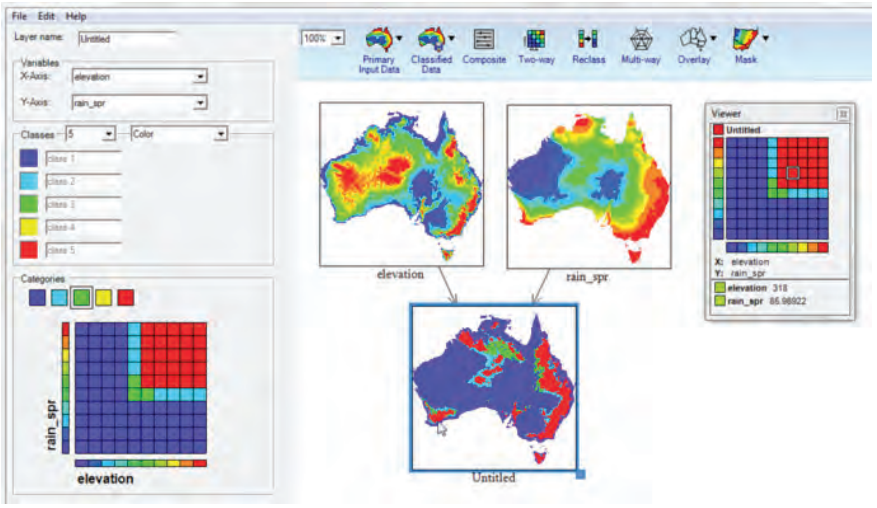
Note: The two-way layer 'Untitled' is a dynamic two-dimensional colour grid showing the relationship between spring rainfall and elevation, with the colour grid set to identify locations where there is a coincidence of high spring rainfall and high elevation classes.

Two data layers are selected from those displayed in the display workspace by using the *Variables* selection on the interface panel. The two-way comparison is visualised in a dynamic two-dimensional colour matrix (that is, a group of coloured grid squares), linked to the map display in the display workspace.

The number of classes for each data layer will be represented on the x and y axes of the matrix (up to 100 classes). The two-way comparison can be classified in up to 10 classes, and class colours changed to specific project requirements. Right-clicking the mouse on any square in the matrix moves the focus of the colour ramp (default red) to that point within the matrix (figure 31).

Alternatively, the two-way comparison map can be customised by assigning a specified colour to selected cells in the matrix. Once a colour under *Categories* is selected, cell selections are made by pointing to desired cells in the matrix shown in the two-way interface panel and left-clicking the mouse (figure 32).

FIGURE 32 Two-way analysis customised to highlight classes of interest

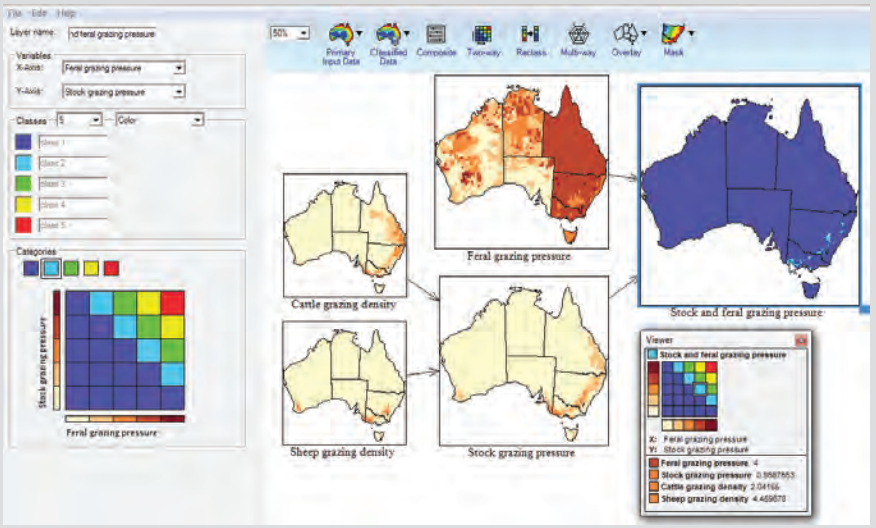


Note: A *Two-way* display workspace showing the relationship between spring rainfall and elevation, customised to highlight locations where there is a coincidence of the highest five classes of rainfall and elevation.

BOX 6 Hypothetical location of soils at risk—two-way comparison

This two-way comparison investigates the coincidence between feral grazing pressure and stock grazing pressure. The areas in red are those locations with a coincidence of high feral grazing pressure and high stock grazing pressure.

The viewer displays the class colour for the area that the mouse is hovering over (in this case green) as well as its position in the two-way matrix. Under the matrix are displayed the values of all contributing layers.

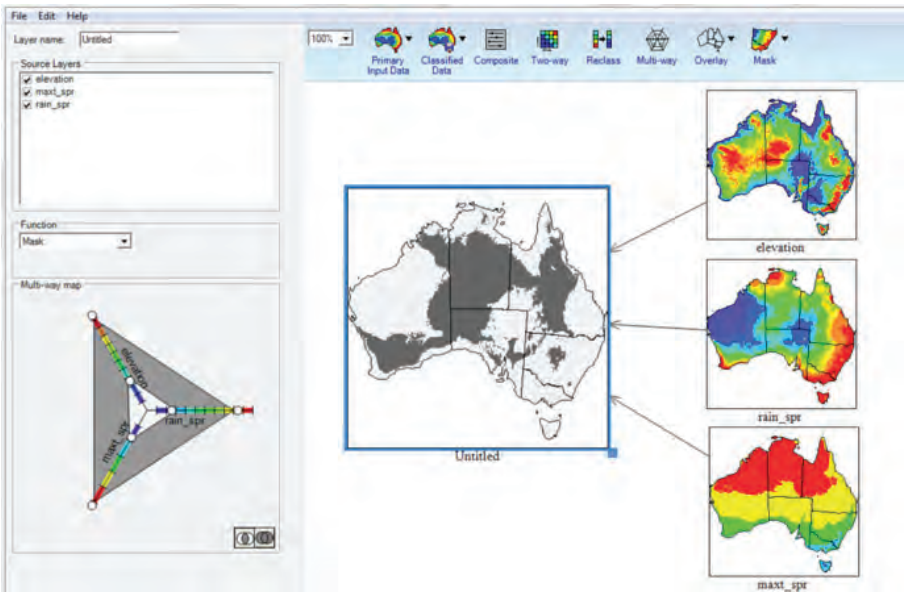


Note: The feral grazing pressure layer is a composite of the *Primary Input Data* layers camel, donkey, goat, horse, pig and sheep distribution equally weighted in MCAS-S.

6.3.2 Multi-way comparison

Multi-way comparison is used when the spatial association of two or more data layers is required (allowing the user to compare the data in two or more of their existing maps). When a map window from the *Multi-way* menu button is dragged into the display workspace, a *Source Layers* panel appears within the interface panel listing the data layers shown in the display workspace. Data layers can be selected for multi-way comparison by checking those listed within this panel. The *Multi-way* analysis uses the radar plot as the basis for visualisation (figure 33). Each vector on the radar plot represents a single selected data layer, scaled according to class values.

FIGURE 33 Multi-way Mask display



Note: The *Multi-way* display interface panel lists the data layers visible in the display workspace, together with check boxes for inclusion in a multi-way analysis. Using the *Multi-way Mask* function, the black areas on the map represent regions that satisfy class values specified by the grey area of the multi-way map (radar plot) in the interface panel. The light grey areas on the map represent regions that do not satisfy these conditions. The mask shows the aggregate or intersection depending on the selection at the bottom of the interface panel.

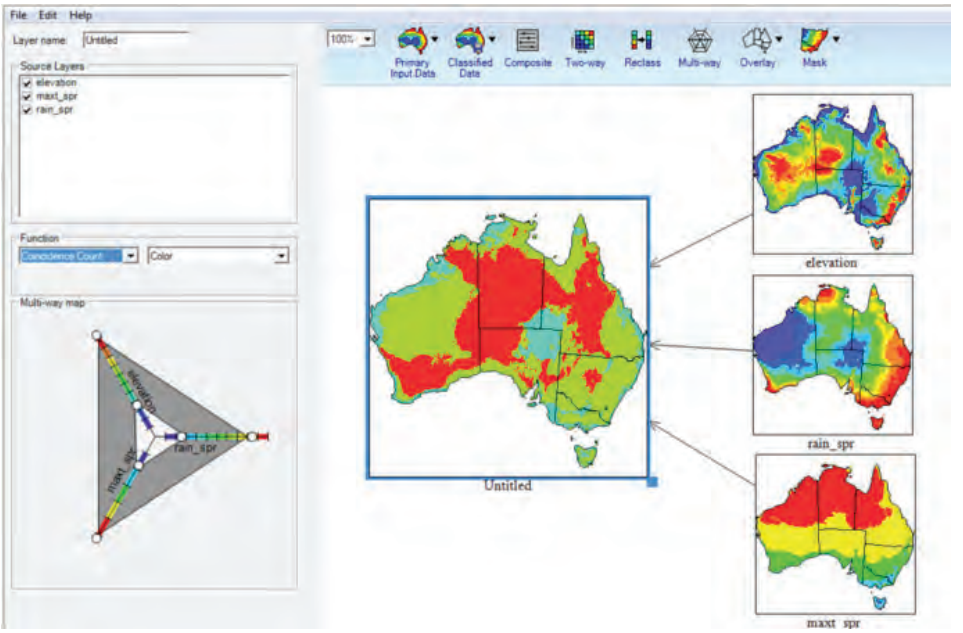
The user can identify sets of class values for each input data layer by adjusting the slider scales on the *Multi-way map* (radar plot) shown in the interface panel. The user can also set maximum and minimum boundary values on each vector in the radar plot. In this way, the user can specify a set of conditions that they wish to satisfy. The geographical regions where this set of conditions applies are shown in the *Multi-way* comparison map window. When the slider scales change, the *Multi-way map* updates to show the area/s of the map satisfying these criteria. For example, the *Multi-way map* in figure 33 shows areas of high elevation, high spring rainfall and high maximum spring temperature.

The *Multi-way Mask* function displays results in a binary format, distinguishing those locations that satisfy criteria values (black) from those that do not (light grey). Using the *Multi-way Mask* function, the grey areas on the map represent regions that satisfy class values specified by the grey area of the *Multi-way map* (radar plot) in the interface panel. The lighter areas on the map

represent areas that do not satisfy these conditions (figure 33). The *Multi-way Mask* function also includes an option to show the aggregate or intersection of input layers selected.

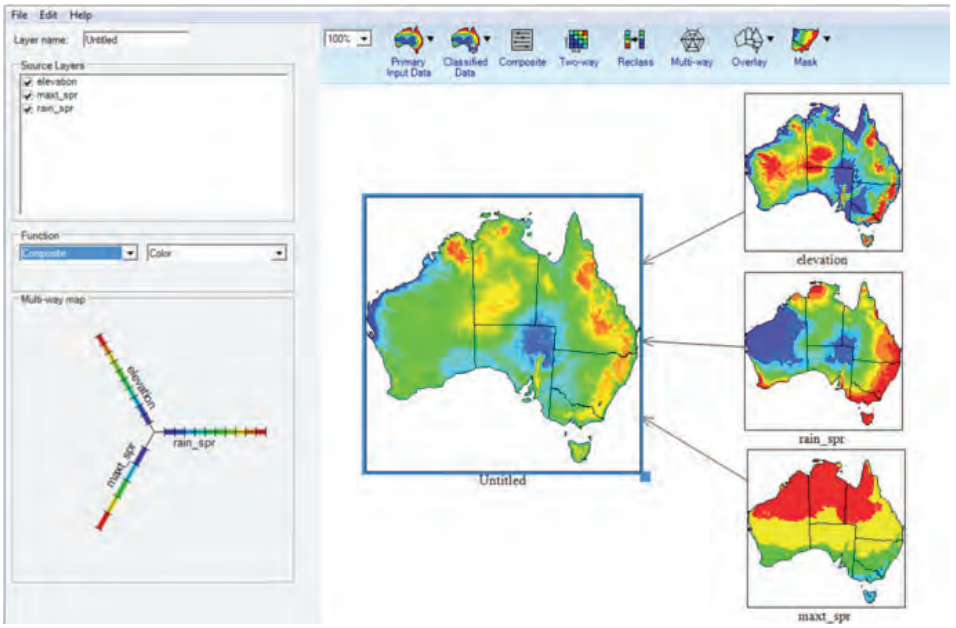
The *Multi-way Coincidence Count* displays a number or count of how many input criteria are met at each pixel in the data layer. The colour scale reflects the number of input criteria which are true (figure 34).

FIGURE 34 Multi-way Coincidence Count display



The *Multi-way Composite* function automatically combines and scales all data layers in a manner similar to the standard composite analysis using an equal interval classification (see 6.4 'Combining data (composite development)'). Therefore, there are no selected criteria values on the radar plot in this type of comparison (figure 35).

FIGURE 35 Multi-way Composite display



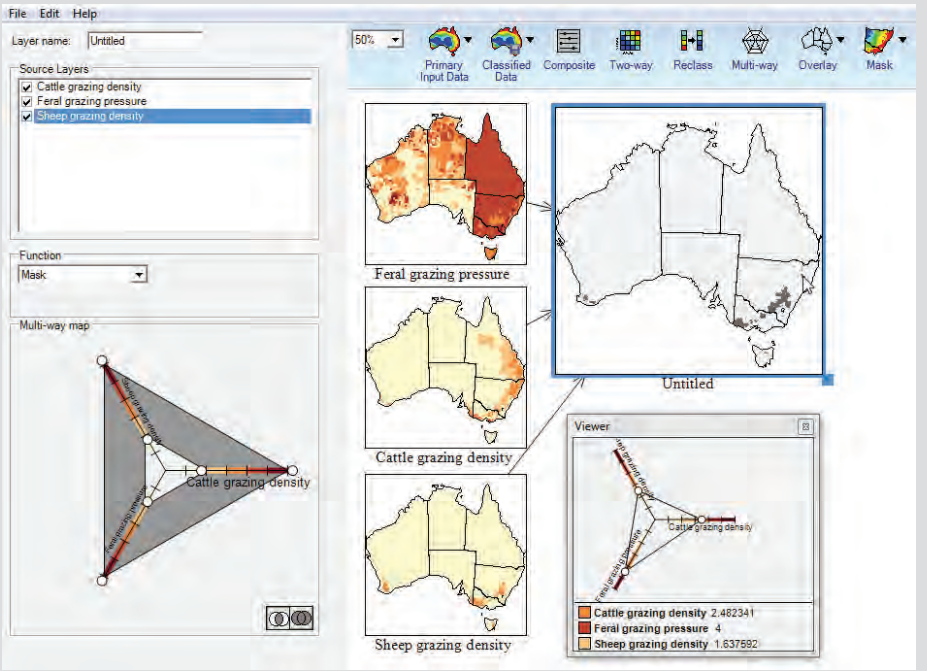
Two-way and multi-way analyses are simple ways of exploring relationships between two or more primary data layers. Two-way and multi-way comparisons created by MCAS-S users can be exported into the *Classified* data folder from where they can later be retrieved by clicking and dragging into the display workspace. For more information on exporting data layers see section 8.1.

More complex problems often require more specific contributions from multiple datasets. Composite development allows the user to specify the way in which each data layer contributes to intermediate and final spatial analysis.

BOX 7 Hypothetical location of soils at risk—multi-way comparison

Here, the coincidence of three input layers is analysed using a multi-way comparison, looking for areas with high grazing pressure from cattle, sheep and feral animals. These areas are shown in grey on the map.

The viewer displays the location on the radar plot for the area that the mouse is hovering over. The values of all contributing layers are displayed under the matrix.



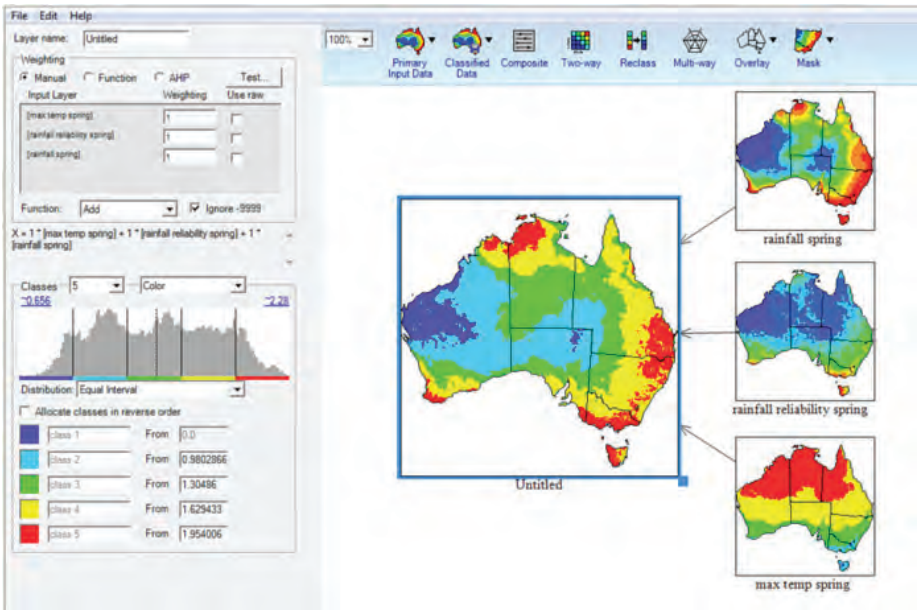
6.3.3 Using a layer as an underlay

To use a particular layer as a backdrop for all the layers in the display workspace, right-click on the layer and select *Use as underlay*. A slider bar will appear in the bottom right of the workspace with a default of 50% transparency. To change this value, slide the bar to the left for less transparency and to the right for more transparency. Underlays can also be used when creating a *New User Layer;* see section 5.6 for more information on user layers.

6.4 Combining data (composite development)

Once individual data layers have been created, they can be combined to construct composite indicators. When a new map window is dragged from the menu button *Composite* into the display workspace, the interface panel for creating a composite appears automatically. The interface panel lists data layers currently on the display workspace and which are available for the construction of the composite (figure 36).

FIGURE 36 A Manual Composite of three Primary Input Data layers



Note: The MCAS-S interface shows the development of a composite indicator based on the unweighted *Manual* combination of three *Primary Input Data* layers, with weightings for each indicator shown at the top of the left panel.

There are several ways to combine the data layers using the interface panel, including:

- the *Manual* option—allows simple weighted combination of data layers
- the *Function* option—enables creation of a composite map from layers using an algebraic expression
- the *AHP* (Analytical Hierarchy Process) option—enables weighted combination of data layers using a pair-wise comparison.

In each case, the combination of the input layers is shown as an expression in the interface panel. The centre of each cell is used to select the underlying values of the input layers. When the layer is exported or a report is built, the calculations are conducted using the resolution selected, again using the centre of the cell and drilling down through the input layers.

MCAS-S recognises and treats the value −9999 as 'no data' or missing values, and raster cells with these values are excluded from subsequent processes. This default setting may be switched off when creating composites.

6.4.1 Manual (default option)

When a composite map window is created, the *Manual* option is the default layer combination method. Each layer has an entry box, where the weighting of the contribution of individual data layers to any composite can be set. MCAS-S applies a simple additive weighting procedure, where cell values for each selected input data layer are multiplied by a nominated weighting factor and then summed. The user can use either raw data layer values or layer values that have been normalised to the range of 0–1 (where 0 = minimum value and 1 = maximum value). The default

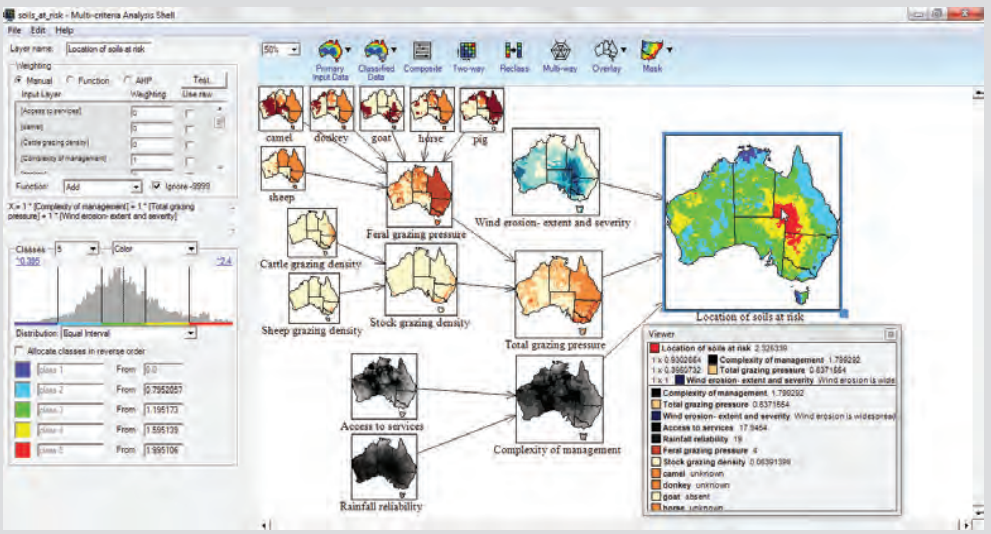
option is to normalise, because it is assumed that layers have been classified into appropriate classes by the users. Raw layer values can be used by checking the *Use raw* box. The composite map dynamically updates as the weightings on the input layers change. Composite data layers may be classified into between two and 10 classes, as per the standard classification procedure.

A number of individual and composite data layers can be included in the display workspace and grouped by theme. This layout creates a map of the relationships between each component in a project. A pathway showing the relationship between each component can be followed all the way through to a final summary composite.

BOX 8 Hypothetical location of soils at risk—manual composite development

To create a layer for 'Location of soils at risk' (see figure 8), the three criteria (wind erosion extent and severity, total grazing pressure, and complexity of management) have been combined using the *Manual* composite function. Each of the input layers has been given an equal weighting so that the composite map shows in red areas, which have a high wind erosion extent and severity, high grazing pressure (created by combining feral, stock and native grazing) and a high complexity of management (created by combining access to services and rainfall reliability).

The viewer displays the class colour for the area that the mouse is hovering over, as well as the weighting of the each of the input layers. The values of all contributing layers are displayed.



6.4.2 Function

The *Function* option allows input datasets to be combined using an algebraic expression. To enter a function, select the *Function* radial button and then press the *Edit* button (see figure 37). This will open the *Function Calculator*. Users can enter an expression combining input layers, including numerals as operands/quantities by clicking on the calculator buttons or typing in text. Input layers can be added to the expression by double-clicking from the list on the left of the *Function Editor* after selecting either the *Classified* or *Raw* option in the bottom left. If typing in text, input layers should be entered using their workspace name in braces { } for raw data values and in box brackets [ ] for classified data values. For example, the simple expression {layer1} * {layer2} will produce a composite map of values that are the product of the raw values of layer 1 and layer 2.

The following functions are supported by MCAS-S:

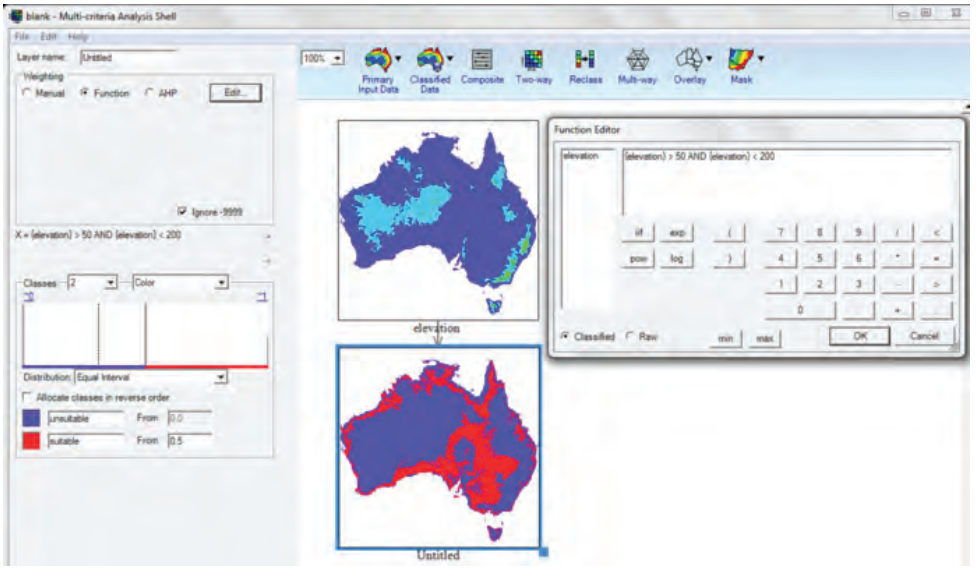
+ - * / < <= = <> > >= exp() log() pow() and or iif() min max

Syntax examples for these functions are shown in table 2. Unless specified, when using a conditional statement, the number 1 will apply where the statement is true and 0 will apply where the statement is false. For example, figure 37 shows areas with a value of 1, coloured in red, that meet the conditional statement (elevation is greater than 50 m and less than 200 m) and areas that do not with a value of 0, coloured in blue.

TABLE 2 Syntax examples for developing a composite map using the *Function Editor*

Syntax	Description
{layer1} * 2	Returns the raw values of 'layer1' multiplied by 2
[layer1] *2	Returns the classified values of 'layer1' multiplied by 2
{layer1} *3 + [layer2]	Returns the raw values of 'layer1' multiplied by 3 and then added to the classified values of 'layer2'
[layer1] / [layer2]	Returns the classified values of 'layer1' divided by the classified values of 'layer2'
pow ({layer1}, 2)	Returns 'layer1' raw values to the power of 2
exp ({layer1})	Returns the exponential of 'layer1' raw values
log ({layer1})	Returns the base 10 logarithm of 'layer1' raw values
{layer1} > 50 and {layer1} < 200	Returns a value of 1 where raw values of 'layer1' are between 50 and 200. Otherwise returns a value of 0 (see figure 37)
iif ({layer1} > 200 and {layer2} > 20, {layer3}, 0)	Returns the raw value of 'layer3' where 'layer1' is greater than 200 AND 'layer2' is greater than 20. Otherwise returns a value of 0
min	Returns the minimum value from a series of layers
max	Returns the minimum value from a series of layers

FIGURE 37 A composite indicator based on a Function combination



Note: The MCAS-S interface shows the development of a composite indicator based on the *Function* combination of one *Primary Input Data* layer. The mathematical expression used to create the composite map is shown in the interface panel. Values of 1 (red) represent where the expression is true, while values of 0 (blue) are where the expression is false.

6.4.3 Analytical Hierarchy Process (AHP)

The *AHP* option provides a more structured alternative to the simple additive weighing procedure used for *Manual* composite development. Input layers are assessed against each other on a pair-wise basis, with judgements made as to relative importance. Selecting the *AHP* option opens a window in the interface panel, which enables users to select relevant layers from those in the display workspace.

Selecting the *Edit* button on the weighting panel opens an *AHP Editor* window that includes an interactive *AHP* matrix enabling the user to rank input layers as less or more important compared to other input layers. Pair-wise weightings can be edited by clicking on the light-grey number boxes in the *Editor* window, and then by selecting a ranking option from the drop-down menu. Once a weighting option has been selected, the relevant number boxes will turn white. Dark-grey boxes cannot be edited. Figure 38 shows an example of *AHP* combination using three input data layers.

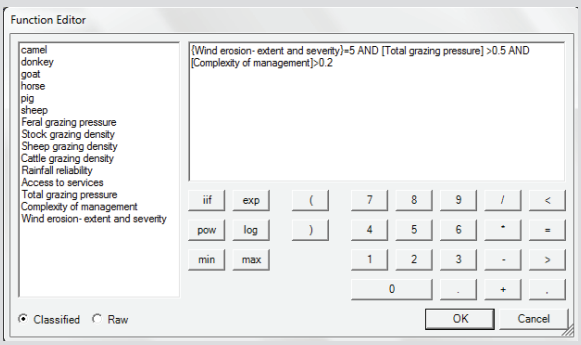
BOX 9 Hypothetical location of soils at risk—function composite development

Function composite development can be used to find areas that meet a certain condition. The formula in the *Editor* window will show areas in red that meet all of the following conditions:

- raw values for the 'Wind erosion extent and severity' layer equal 5 (which, referring to the text file for this layer, means 'Wind erosion is widespread and severe') AND
- classified values for the 'Total grazing pressure' layer that are allocated to classes 3, 4 or 5 ('Total grazing pressure') AND
- classified values for the 'Complexity of management' layer that are allocated to classes 2, 3, 4 or 5 ('Complexity of management').

Areas that do not meet these criteria are shown in blue.

The *Viewer* displays the class colour for the area that the mouse is hovering over (in this example, the colour is red because it is an area that meets the condition). The values of all contributing layers are displayed under the matrix. The 'Wind erosion extent and severity class' is equal to class 5 ('Wind erosion is widespread and severe'), 'Total grazing pressure' is greater than 0.5 and 'Complexity of management' is greater than 0.2.



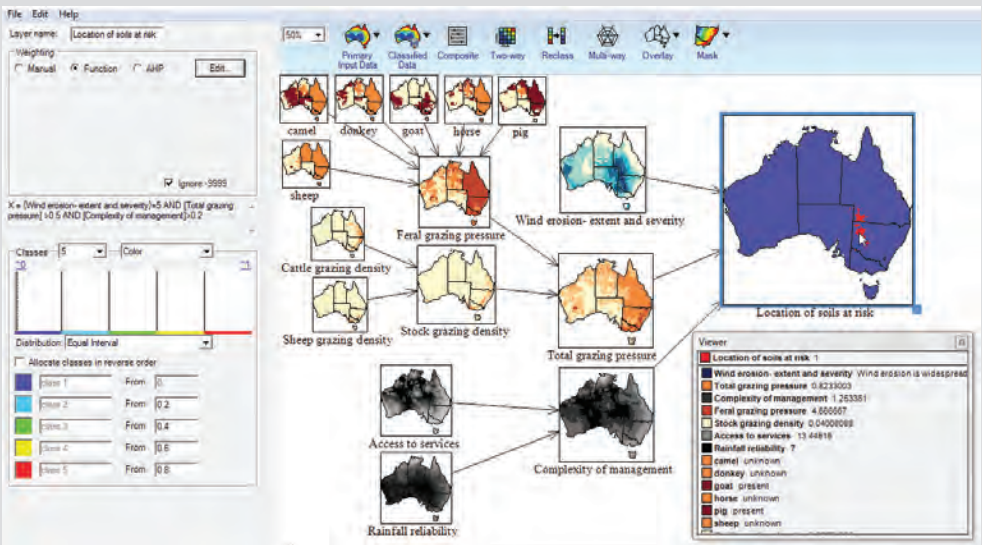
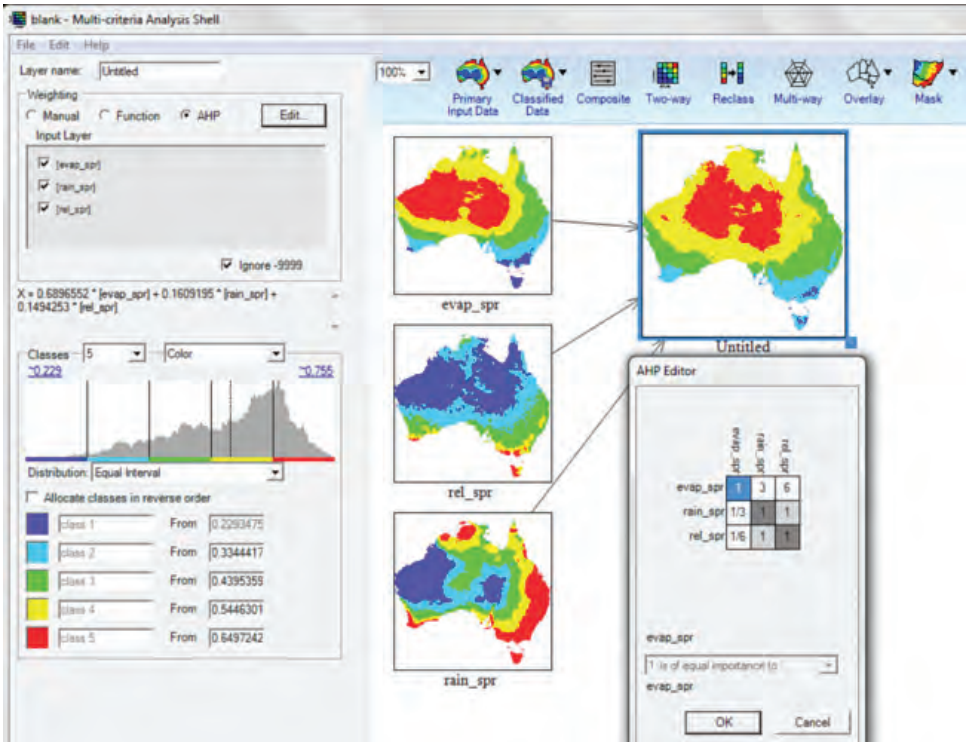


FIGURE 38 A composite indicator based on AHP combination



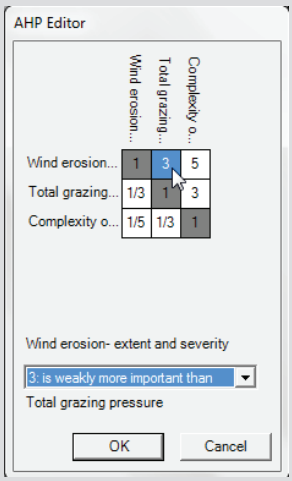
Note: The MCAS-S interface shows the development of a composite indicator based on the AHP combination of three *Primary Input Data* layers.

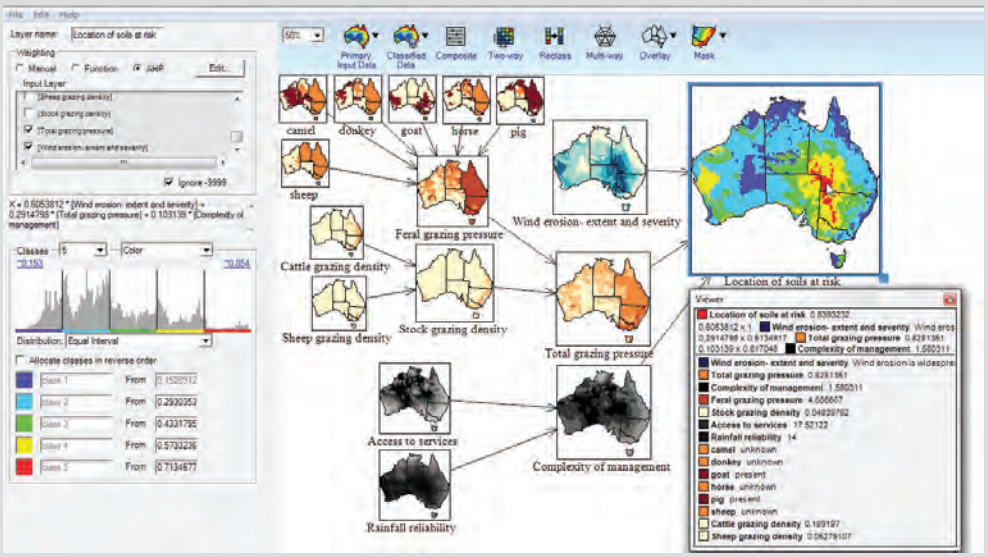
In order to save two-ways, multi-ways and composite data layers from the active map window, see the *Export* function in section 8.1. Exporting data layers adds them to the *Classified Data* folder from where they can be added into MCAS-S projects.

BOX 10 Hypothetical location of soils at risk—AHP composite

The same input data in boxes 8 and 9 can be used to create a composite using the AHP function; this way the relative importance of input layers can be allocated. In this example:

- 'Complexity of management' is deemed 'strongly less important' than 'Wind erosion extent and severity'
- 'Complexity of management' is deemed 'weakly less important' than 'Total grazing pressure'
- 'Wind erosion extent and severity' is deemed 'weakly more important' than 'Total grazing pressure'.





6.5 Other features

6.5.1 Viewer window

When the mouse is poised over any map window in the display workspace, the *Viewer* window (see figure 6) dynamically displays details from the data layer in the active map. The *Viewer* window provides the values from the data layer, and additional information about the map location at the point of the arrow. The *Viewer* window provides a variety of information depending on the type of map window that is open at the time (for examples, see figures 39, 40, 41, 42 and 43). The viewer can be closed by clicking the Close (X) button. To reopen, go to the *Edit* drop-down menu and click *Show Viewer*.

FIGURE 39 Components of Viewer window (shown for a Two-way analysis)

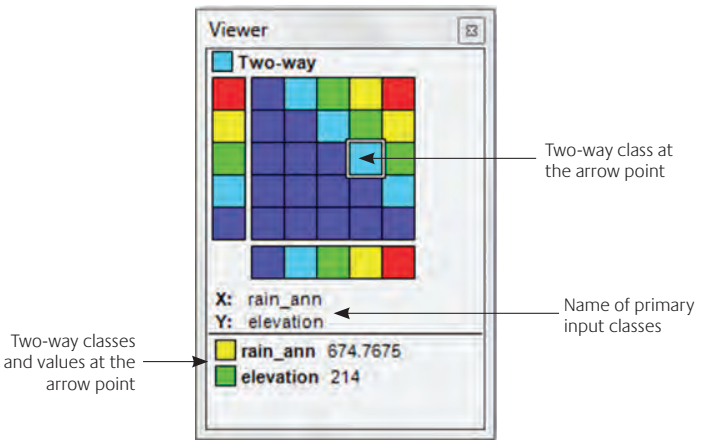
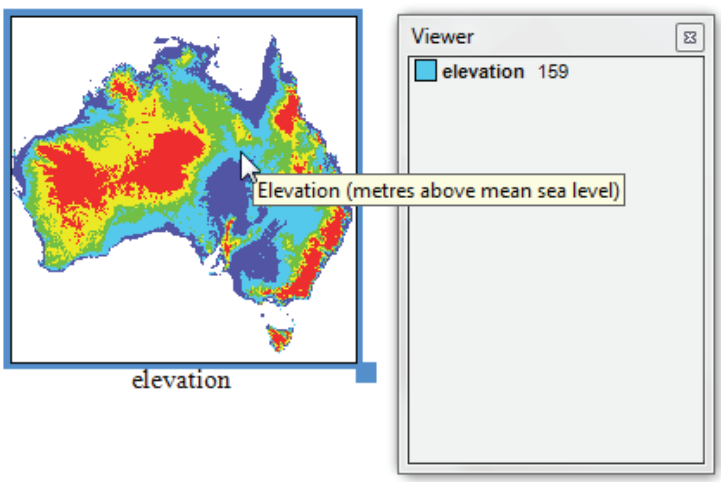
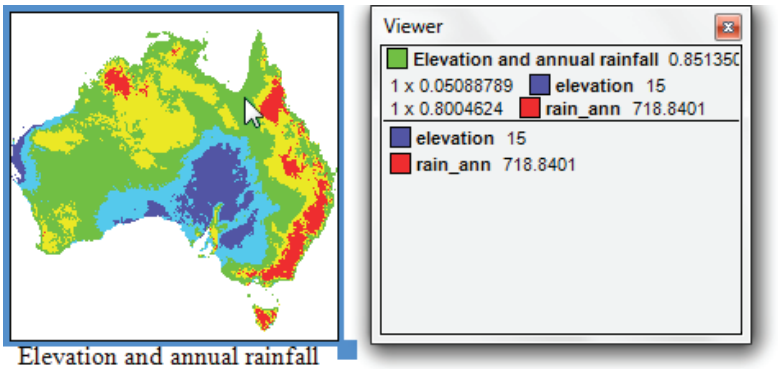


FIGURE 40 Viewer for a Primary Input Data layer



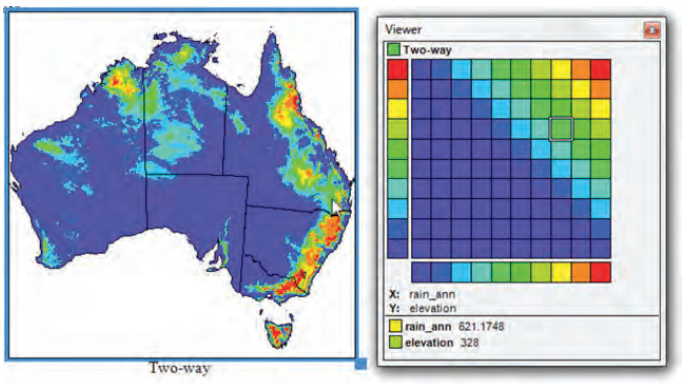
Note: The *Viewer* provides information about points on an active map when the mouse is placed over the map window. In this example the *Viewer* displays the value for a specific grid cell of the *Primary Input Data* layer elevation.

FIGURE 41 Viewer for a Composite Data layer



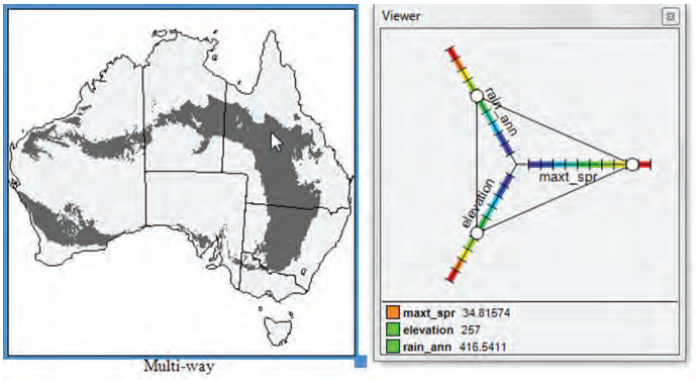
Note: In this example, a composite map ('Elevation and annual rainfall') has been created from two data layers. The viewer displays the 'normalised' value of the two cells, the weighting of each layer and their values for a specific grid cell.

FIGURE 42 Viewer for a Two-way analysis



Note: Two-way *Viewer* shows the layer value of the selected cell on a 10 x 10 matrix that has been created from two data layers. The *Viewer* displays the value of the selected cell in relation to the rest of the matrix. The values for the specific grid cell are displayed at the bottom of the *Viewer*.

FIGURE 43 Viewer for a Multi-way comparison



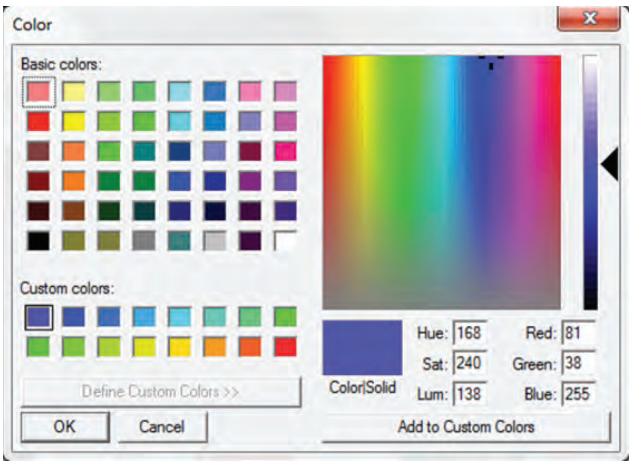
Note: The *Viewer* displays the values of the input layers for a specific grid cell. The *Multi-way Viewer* shows the value of the selected cell on a *Multi-way* comparison that was created from three data layers (elevation, maximum spring temperature and annual rainfall).

6.5.2 Changing class colours and names

A default blue–red colour ramp is applied automatically to data layers in MCAS-S. An additional set of colour ramps, including a black and white option, can be selected from MCAS-S interface panels. New colour ramps added in Version 3.1 include: reds, blues, purples, oranges and greens, pink to green and purple to orange.

In the data layer information panel shown separately in figure 6, class colours can also be changed from the default colours by either left or right-clicking on the class colour box. A Colour window appears and basic or custom-defined colours can be selected (figure 44).

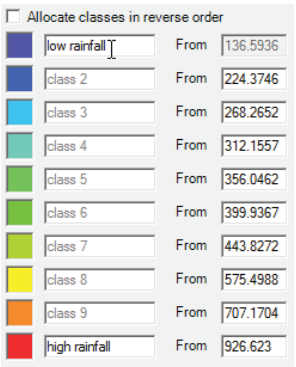
FIGURE 44 The Colour window—Define Custom Colours option



Note: The *Colour* window can be opened by left or right-clicking on a class colour box and then the *Define Custom Colours* option can be selected.

Class names can also be added in the interface panel (figure 45). Values within layers can be classified as required and, for example, named 'Low', 'Medium' or 'High' rather than the default values, 'class 1', 'class 2', 'class 3' and so on. Categorical data classes can also be renamed; for example, when grouping vegetation into floristic classes such as 'Eucalyptus', 'Callitris' and 'Casuarina'.

FIGURE 45 Each class can be named by typing directly in the class text box



6.5.3 Adding colour ramps

MCAS-S users can create and save personalised colour ramps for use in projects. To create a colour ramp accessible for all MCAS-S projects, simply add an entry to the *ramps.txt* file, which is located in the MCAS-S installation folder (where the *MCAS.exe* file is located). To save a colour ramp specific to a particular project, save a file called *ramps.txt* within the *Data* folder.

Colour ramp entries should be saved using the following convention (separated by commas with no spaces):

'colour ramp name','start colour code','middle colour code','end colour code'

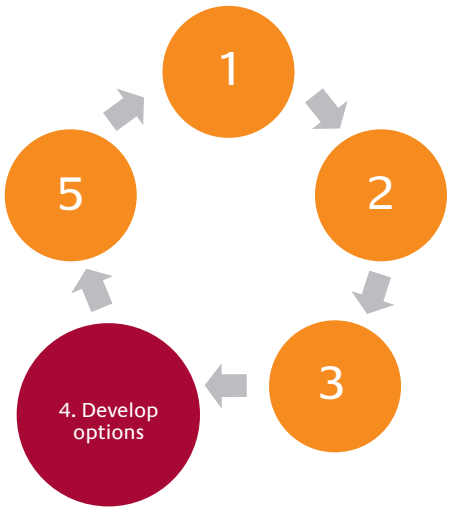
For example, a colour ramp called 'YlGnBl' starting at yellow (FFFFD9), going through green (41B6C4) to blue (061D58) would be written as:

YlGnBl,FFFFD9,41B6C4,061D58

Colour codes should be saved as six-digit hexadecimal codes (colour codes shown in the MCAS-S colour window in figure 44 are in RGB and will need to be converted).

7 STEP 4: DEVELOP OPTIONS

The development of options in an MCA process involves testing different ways to assemble and combine information, taking into account alternative perspectives on available data, science, economics and policy options to inform management. MCAS-S can show scenarios that represent different stakeholder perspectives and alternative pathways forward. Decision-makers can use this information to make an informed choice.



Decision-makers may wish to develop and compare options in order to:

- show how changing the weight of input data affects or does not affect the final result,
- identify which factors contribute to high ranking areas
- see how much input values may need to change to achieve a different result
- help to achieve a consensus view, or appreciate why a consensus cannot be reached
- focus on areas or data layers of interest or that need improvement
- identify potentially beneficial management options.

MCAS-S users can develop options by:

- adding or removing primary data inputs,
- reclassifying inputs to highlight different attributes
- creating new user layers to capture expert knowledge, update data, add information about data reliability or explore hypothetical situations
- changing the way primary data are combined by comparing two-way, multi-way and different composite weightings.

The live-update functionality of MCAS-S enables rapid reworking of all the elements underpinning the development of options. This is particularly valuable in workshop situations, as it makes the construction of each layer transparent and relationships can be explored and modified easily to quickly feed all the way through the analysis.

In the hypothetical soils at risk example some options are:

- Changing the weight of grazing pressure or management complexity: Does the priority area change? This can be done using a sensitivity analysis.
- Reducing the feral grazing pressure or stock grazing pressure: Does this reduce the risk of soil erosion? This can be done by substituting new functions for feral and stock grazing and comparing the end result.

These examples include only a few methods to develop and evaluate options. Users may find other examples and references on the MCAS-S website daff.gov.au/abares/data/mcass.

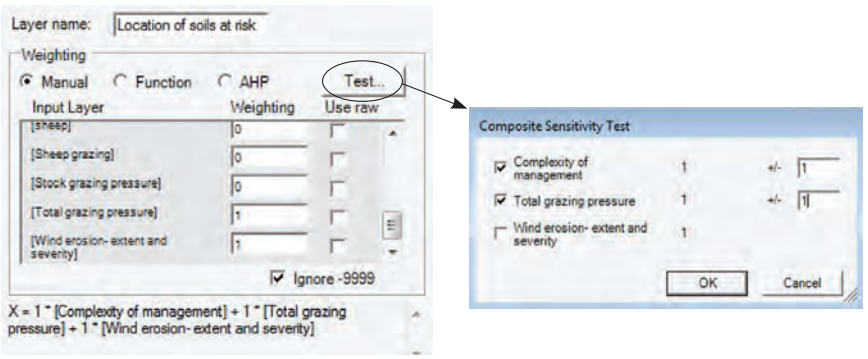
7.1 Sensitivity analysis

When creating a composite using the Manual option, it is possible to use a sensitivity analysis to test how changes to the weighting of the input layers affect the composite layer. This can help decide whether the level of error or uncertainty in a data layer is acceptable for the analysis or better data is needed, whether a particular input is overly influencing the final outcome and should have its weighting reduced, or show if different opinions about the importance of inputs lead to markedly different outcomes.

Selecting the *Test* button on the weighting panel will open a dialogue box that lists the current input layers and their weightings. When an input layer is selected a weighting test value will appear, the default value of which is plus or minus half the original weighting (figure 46). This default value can be changed to the desired value.

The layer for 'Location of soils at risk' was created using a manual composite adding three sub–criteria, each equally weighted with a value of 1. A decision-maker may use the sensitivity analysis to test how changing the weights or removing the sub-criterion 'Complexity of management' or 'Total grazing pressure' affects the final layer. Figure 46 shows the *Composite Sensitivity Test* window with 'Complexity of Management' and 'Total grazing pressure' set to plus or minus 1.

FIGURE 46 An MCAS-S interface showing a sensitivity analysis for a Manual composite layer

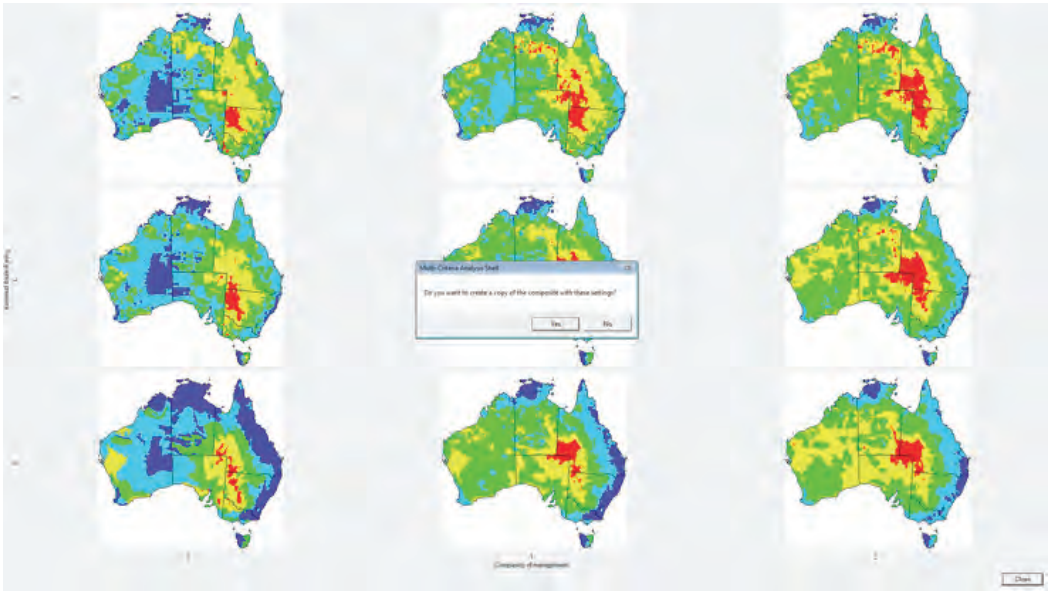


Note: In this example, the sensitivity of a *Manual* composite is tested by adjusting the weight of 'Complexity of management' and 'Total grazing pressure' by plus or minus 1 while leaving the weight of 'Wind erosion extent and severity' constant at 1.

Once two input layers have been selected and the test values set, clicking the OK button will display nine composites based on the range of values chosen (figure 47). Any of the nine layers can be added to the MCAS-S display workspace by simply clicking on them. This action will create a new composite rather than overriding the original composite.

In this example the 'Complexity of management layer' strongly influences the area of soils at risk in Queensland. Removing the 'Complexity of management' layer, as shown in the three left options, results in little to no area at risk (red) in Queensland. This could influence decisions about policies or programs.

FIGURE 47 A sensitivity analysis based on the input layers and test values chosen in figure 46



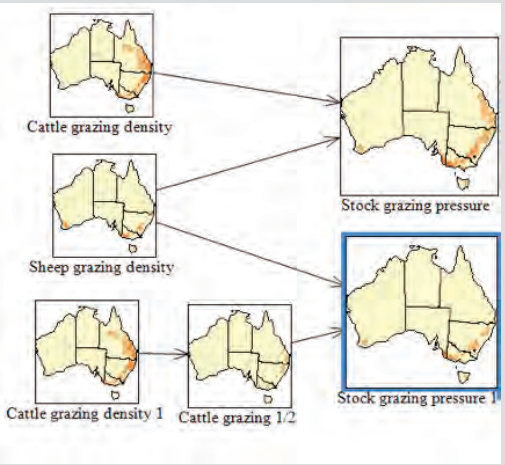
Note: the centre layer shows the original composite with weights of 1 and 1 for input layers 'Complexity of management' and 'Total grazing pressure'. The vertical axis shows the effect of changing the weight of 'Total grazing pressure' from 0 to 2. The horizontal axis shows the effect of changing the weight of 'Complexity of management' from 0 to 2. The weight of the third input 'Wind erosion extent and severity' remains constant at 1 for each of these nine options. If one of the nine options is clicked, a copy of this layer with the chosen weights can be added to the workspace.

Note that sensitivity analysis cannot be completed using *Function* or *AHP* composites. With *Function* and *AHP* composites, the *Edit* button is displayed in place of the *Test* button.

BOX 11 Hypothetical location of soils at risk – Develop options

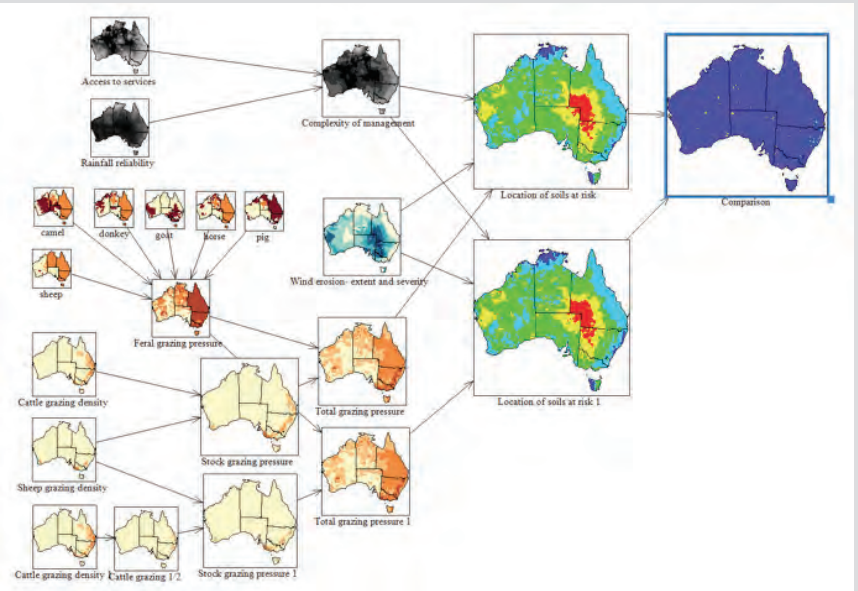
Other MCAS-S functions previously discussed in this manual can also be used to develop options. For example comparing different grazing scenarios could be useful for a land manager. The effect of reduced cattle grazing density can be estimated by adding a new 'Cattle grazing density' layer with half the grazing density. The manager can see not only the change in the sub-criteria 'Stock grazing pressure' but also the change in the 'Location of soils at risk'. In this case the new layer 'Stock grazing pressure 1' shows less area at risk in Queensland more closely resembling the 'Sheep grazing' layer.

The MCAS-S software is able to show the two scenarios side by side including all inputs which contribute to each scenario. Use of a two-way analysis shows the difference between the output 'Location of soils at risk' in the two scenarios. While there are not major changes across much of Australia even small changes may be significant.



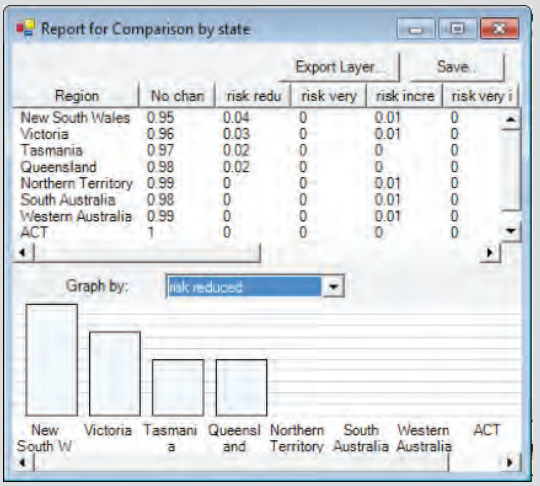
Note (left): the new layer 'Cattle grazing' was created using the function {Cattle grazing 1}/2 and setting the 5 classes of 0–1, 1–2, 2–5, 5–10 dry sheep equivalent per hectare to match the original 'Cattle grazing density' layer.

Note (below): The top coloured layer 'Location of soils at risk' is the original scenario and the bottom shows the new scenario 'Location of soils at risk 1'. The very right hand layer is a two-way where dark blue represents areas where the risk class has not changed, light blue shows a decrease of one class, green shows an increase of more than one class (not observed), yellow shows an increase of one class and red shows an increase of more than one class (not observed).



BOX 11 Hypothetical location of soils at risk – Develop options (continued)

The *Report* function discussed in the next chapter can also provide more details about which regions show larger areas of change.



This report shows the least change is recorded for ACT (100 per cent unchanged), with risk reduced by one class in New South Wales (four per cent) Victoria (three per cent), and Queensland and Tasmania (two per cent), and slight increases with one per cent of the area of South Australia, New South Wales, Victoria, Northern Territory and Western Australia showing risk increased by one class. A land manager in Queensland may decide that reducing the density of cattle may be combined with management of feral animals to have an impact. Please note that other information such as density of feral animals, and available fodder per hectare, may also be useful depending on the decision being made. A project at national scale may indicate areas of relative risk while a regional analysis may be more suitable to compare management options.

8 STEP 5: REVIEW AND REPORT

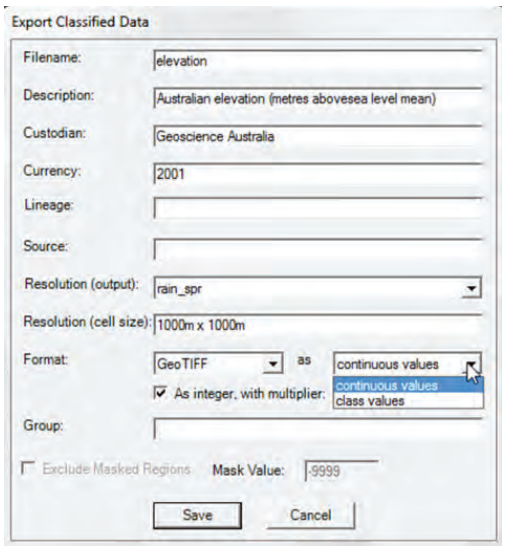
Exporting and reporting options are useful if the outputs are to be used in other software or models, or are to be presented in reports and publications.

MCAS-S has a variety of methods for exporting and reporting on data layers. Data can either be exported as a raster file for use in other GIS software, or as a KML file for use in the Google Earth application. MCAS-S allows tabular reporting on any layer in the workspace against the classes or regions in any of the mask layers. This information can then be exported as tables or new layers.

8.1 Exporting

The *Export* function saves the data layer in the active map window. Any data layer can be exported, including composites, two-ways and multi-ways. Exported data can be saved by right-clicking on the active map window and selecting *Export*. An *Export Classified Data* window will appear; this allows the user to give the exported layer a filename, set the resolution to an existing layer, fill in metadata, select the format and save it in a group folder under *Classified Data* (figure 48).

FIGURE 48 Export Classified Data window



Layers can be exported as a GeoTIFF or ASCII file. Note that MCAS-S only reads exported files as GeoTIFFs, thus ASCII formatted files should only be used for other applications.

If a layer is exported using 'class values', it will be saved with the current number of classes and colours, which cannot be changed when brought back into MCAS-S. If a layer is saved using 'continuous values', the layer will behave like a primary data layer when brought back into MCAS-S, meaning that colours and classes can be reclassified. When the 'continuous values' option is selected the user can also choose whether to export the data layer as an integer (to remove decimal places and reduce the size of the exported layer) or to retain the decimal values. To create a smaller integer output without losing the precision of the original data layer the user may choose to apply a multiplier. For example, applying a multiplier of 10 will multiply the value of every pixel by 10 turning 0.1 into 1 thus preserving the values from one decimal place while creating a smaller integer data layer.

Exporting layers to specific groups/folders may be useful for ordering large numbers of derived data layers that can be structured according to project needs. To create a new group folder, enter a new name into the *Group* field. Typing the name of a previously created folder will add the exported data layer to the existing folder alongside any data layers previously exported to that group.

If the exported layer has not been allocated to a group, it can be directly retrieved from its saved location under the *Classified Data* menu item. Alternatively, if the layer has been allocated to a group, it can be retrieved under the folder with the relevant group name.

8.2 Reporting

MCAS-S allows users to generate statistical reports for regions (saved in the *Mask* folder), points (saved in the *Overlay* folder), and to report on correlations between two input data layers within MCAS-S. It is also possible to show MCAS-S layers in Google Earth (see section 8.2.4), and as an underlay (see section 6.3.3).

8.2.1 Report by region

The *Reporting* function will generate statistics for regions, defined by user-nominated mask data layers, and export these to a summary report.

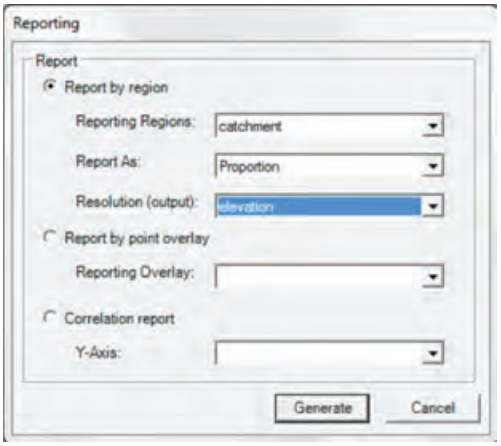
To generate a report, right-click on the active map window and select *Reporting*. A *Reporting* window will appear (figure 49). The *Reporting* window allows the user to select the mask data layer that contains the reporting areas, to select from the reporting options *Proportion* or *Cell Counts*, and to choose the resolution for reporting. The *Proportion* option is useful for calculating proportional amounts of each class, whereas the *Cell Counts* option is useful for estimating areas of each class in each reporting region. Each option will report the maximum, minimum, range, mean, standard deviation and sum for each reporting area. These values are useful for primary layers, but not as useful for composites, two-ways and multi-ways because in such cases, the statistics are calculated on normalised values. Now that MCAS-S can accept primary data with varying resolutions, the user will need to choose the resolution for their reporting based on any of the layers in the display workspace.

An interactive tabular report is generated providing class and summary statistics for each region (see box 12). Clicking on the name of a region, or clicking and dragging to select a set of regions, will highlight the corresponding locations on layers in the display workspace. Combinations of class values can be similarly selected and located on map layers by clicking and dragging. Tabular data can be saved to a .csv file, which is suitable for manipulating in MS Excel, by pressing the *Save* button in the top right-hand corner of the table.

The reporting function also provides for the generation of new spatial layers. Pressing the *Export Layer* button in the top right-hand corner of the table opens a dialogue box that requires the selection of a statistic (class value, maximum, minimum, range, mean, coefficient of variation, sum) and file name for the new layer. When saved, a new layer with the relevant statistic for each reporting unit (such as region or catchment) is exported to the *Classified Data* folder. This enables the generation of new regional layers for both continuous and categorical layers.

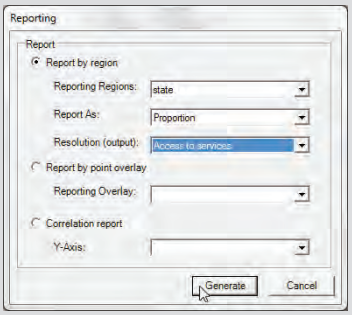
Note that for masked data layers, the reporting function should only be used when the *Mask View and Data* option is selected.

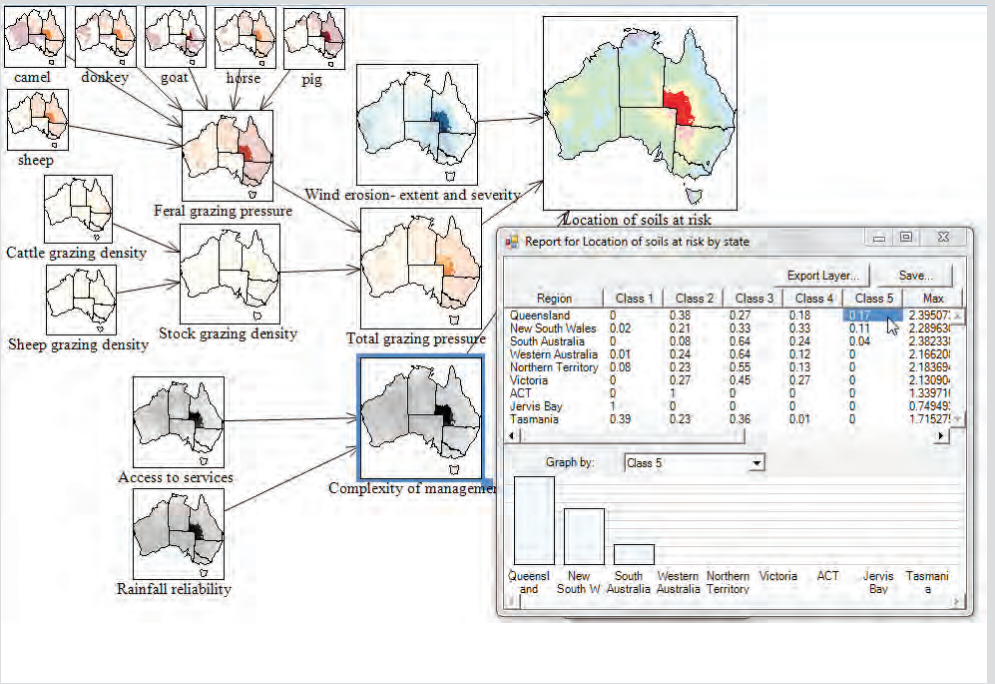
FIGURE 49 Reporting window obtained by right-clicking on the active map window and selecting Reporting



BOX 12 Hypothetical location of soils at risk—reporting

A state report has been generated. The high-risk class has been highlighted for Queensland, which then highlights the relevant data in each of the input layers.




camel
donkey
goat
horse
pig
sheep
Feral grazing pressure
Wind erosion- extent and severity
Location of soils at risk
Cattle grazing density
Sheep grazing density
Stock grazing density
Total grazing pressure
Access to services
Rainfall reliability
Complexity of managemer
Report for Location of soils at risk by state
Export Layer...
Save...
Region | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Max
Queensland 0 0.38 0.27 0.18 0.17 2.39507
New South Wales 0.02 0.21 0.33 0.33 0.11 2.28963
South Australia 0 0.08 0.64 0.24 0.04 2.38233
Western Australia 0.01 0.24 0.64 0.12 0 2.16620
Northern Territory 0.08 0.23 0.55 0.13 0 2.18369
Victoria 0 0.27 0.45 0.27 0 2.13090
ACT 0 1 0 0 0 1.33971
Jervis Bay 1 0 0 0 0 0.74949
Tasmania 0.39 0.23 0.36 0.01 0 1.71527
Graph by:
Class 5
Queensl and
New South W
South Australia
Western Australia
Northern Territory
Victoria
ACT
Jervis Bay
Tasmani a

8.2.2 Report by point

The values for points in an overlay can be calculated from of any data layer in the workspace providing the project has a point dataset in the overlay folder. To generate a tabular report right click on a data layer, select *Reporting*, select the option *Report by point overlay* and use the drop-down list to select the point overlay – for example 'Capitals'. Note that line overlays may appear in this list but will not output a complete report. Once the options are selected and the *Generate* button is clicked the user will be prompted to save the resulting .csv output file in order to see the result. The report will automatically open if MS Excel is loaded. The report will show the names of the points in the first column and the values of the data layer which the report has been run on and any contributing layers in the subsequent columns.

8.2.3 Correlation report

A graphical correlation plot can be generated for a two-way analysis by right clicking on any layer, or by selecting any two layers using the shift key and selecting *Reporting*. The *Correlation report* shows the frequency of class values for the layer selected against the frequency of class values for another layer selected by the user. The correlation coefficient is provided at the bottom of the chart. This report can be saved using the *Export* button.

8.2.4 Showing a map in Google Earth

The *Show in Google Earth* function can be chosen by clicking the right mouse button on a layer in the MCAS-S workspace. This function enables the display of a selected map window in the Google Earth visualisation program. Execution of this function requires the installation of appropriate Google Earth software and an internet connection.

8.3 Keeping records

In many cases it is useful to record the outcome of an MCAS-S project and decision criteria. This section looks at functions that are useful for keeping records of MCAS-S projects and how data layers have been classified. Each of these functions is accessible by right-clicking on any layer on the desktop.

8.3.1 Copying a log as text

The *Copy Log As Text* function copies a log of processing steps associated with a data layer in the active map window to the clipboard. The log can then be pasted into another document.

8.3.2 Copying a layer as an image

The *Copy Layer As Image* function copies a selected map window to the clipboard as an image, which can be pasted into another document.

8.3.3 Saving an image, legend and histogram

The *Save Image* function provides the options of saving the selected map window as a .png image file, saving the legend (with or without values) as an .emf file and saving the histogram (with or without minimum and maximum values) as an .emf file.

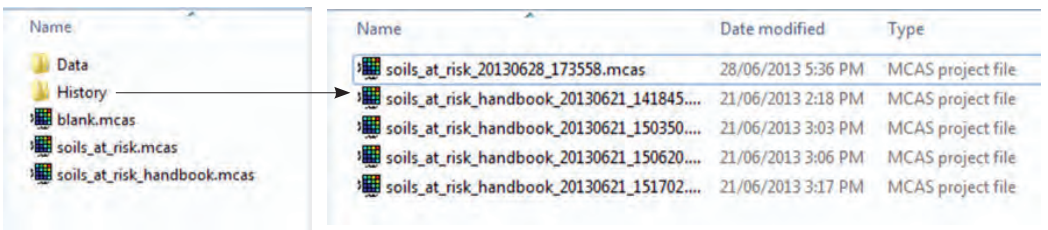
8.3.4 Printing

The *Print* function allows the user to print the display workspace directly. In some cases, the 'print screen' function or some other image capture method may return a more suitable image.

8.3.5 Restoring a previous version of the MCAS-S workspace from the *History* folder

MCAS-S version 3.1 automatically saves date stamped copies of open MCAS-S projects in the *History* folder every time the user saves a MCAS-S project by clicking *Save* from the *File* menu. This folder is automatically generated below the *Data* folder in the user's workspace once an MCAS-S project is saved. Copies of the open MCAS-S project inside this folder are named 'name_yyyymmdd_hhmmss' (figure 50). If the user wishes to return to a previous version of the workspace the time stamped project can be copied out of the *History* folder and pasted next to the *Data* folder and opened for use. Please note: if the date stamped MCAS-S project is opened in the *History* folder the project will not be able to access the data and there will be an error message. The *History* folder only saves a copy of the MCAS-S workspace. If changes have been made which affect the data these will also be reflected in projects restored from the *History* folder.

FIGURE 50 File structure of the History folder



Note: Files in the *History* folder CANNOT be run from the *History* folder. These files must be copied out of this folder and saved next to the *Data* folder in order to be opened.

8.3.6 Other software for keeping records

Other software may be useful to record details of the MCAS-S project and prepare means-to-an-end diagrams.

Details that are important to record for future reference and to share with colleagues and stakeholders will vary depending on the complexity of the MCAS-S project. This may include: how primary data layers have been selected and classified, which layers have been chosen from a time series and how these have been combined, explanations of models and functions used for composite, multi-ways and two-way layers including reference documents containing the justifications for these choices, or links to other MCAS-S projects which contain inputs and outputs.

Software packages which enable creation of flowcharts, workflows or mindmaps can be useful. Some examples include PowerPoint smart art, Compendium (compendiumng.org) or Mindjet (mindjet.com). When choosing a tool users should consider who the project will be shared with, what software they already have access to, how much it will cost, and whether other parties need to contribute to the document online or in a shared location.

9 ERRORS AND FEEDBACK

The MCAS-S development partners are working to improve the functionality of the MCAS-S tool. Comments and suggestions that increase the usefulness of this decision support tool are appreciated and will assist with any future developments.

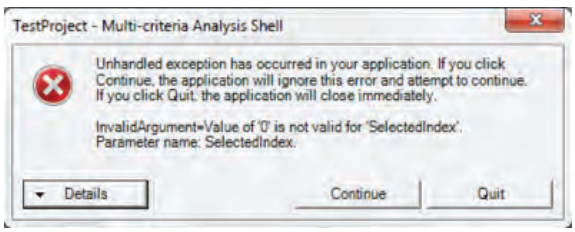
Director: Land Use and Management
ABARES
GPO Box 1563 Canberra ACT 2601
land_management@daff.gov.au

9.1 Common error notifications

MCAS-S users will occasionally encounter issues with the software. When an issue is encountered the user may see a popup box showing 'unhandled exception' (figure 51) or a cross through a data layer in the MCAS-S workspace (figure 52).

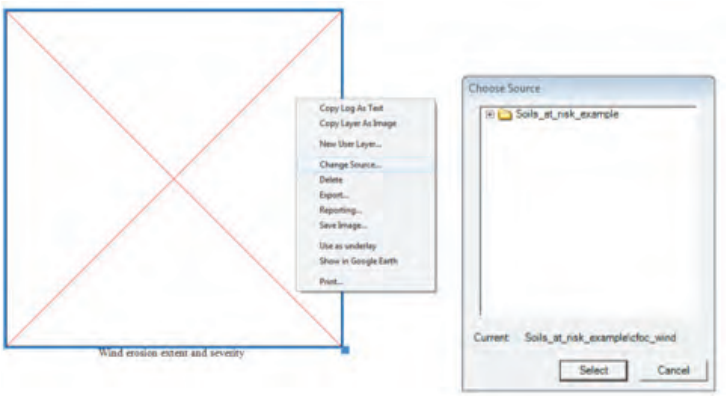
In response to an unhandled exception the user may wish to click *Details* to view more information and *Continue* to close the error box and return to the MCAS-S project or *Quit* to close the MCAS-S project. Quitting will lose any unsaved changes. In response to a cross through a data layer the user may remove the data layer (right click—*Delete*) and then re-add the layer, or update the source of the data layer (right click—*Change Source*). Users should be careful to ensure that the data source chosen is correct as the layer name will remain the same regardless of what data source is selected and this may lead to misinterpretation of the results.

FIGURE 51 Unhandled exception error window


TestProject - Multi-criteria Analysis Shell
Unhandled exception has occurred in your application. If you click Continue, the application will ignore this error and attempt to continue. If you click Quit, the application will close immediately.
InvalidArgument=Value of '0' is not valid for 'SelectedIndex'. Parameter name: SelectedIndex.
Details
Continue
Quit

Note: The unhandled exception window shows that MCAS-S cannot complete a requested task. The user may click *Continue* to close the error box and return to the MCAS-S project or *Quit* to close the MCAS-S project.

FIGURE 52 A missing data source shows as a cross



Note: If a data layer has been moved out of the *Data* folder, been renamed or become corrupted MCAS-S will no longer be able to find this data layer and will show a red cross. Users can delete or change the source of the data layer using the right click options.

9.2 Checking and correcting common errors

9.2.1 MCAS-S software fails to install or is unable to be opened for first use

When the MCAS-S software has not installed correctly the user may need to:

- Check the website for the most recent version of MCAS-S.
- Check that the software is installed in a folder on a local hard drive.
- Check that the dotnetfx executable (.exe) file is also installed on the computer (the Microsoft dotnet framework is a software component that can be added to the Windows operating system. It provides pre-coded solutions to MCAS-S and some other games and graphics programs. If this is not present the dotnetfx.exe this can be freely downloaded).
- Try to repair or uninstall and reinstall the MCAS-S software.

Unfortunately MCAS-S is not currently Apple compatible but can be run on Windows simulators.

9.2.2 An error message is repeatedly encountered in an MCAS-S project

If an MCAS-S project has been opened but an error is repeatedly encountered this is usually due to incompatible or corrupted data. To rectify this error the user can:

- Follow the instructions in section 5.5 creating your own data and on the MCAS-S website daff.gov.au/abares/data/mcass
- Check that the data folder is saved alongside the project, the *Data* folder contains folders *Primary*, *Classified*, Overlay and *Mask* and that each of these folders contains data layers in the appropriate format. If layers have been removed or renamed in the data folders since the last use these layers these will need to be removed from the MCAS-S project or the source may be corrected as described in section 9.1.

- Ensure that the extent and projection is the same for all layers—bringing in a layer which does not match other layers in the project is the most common reason why a project which has previously been working will become corrupted.
- Ensure that care is taken moving or copying data between folders. A GIS program should always be used when moving or copying ESRI grid files.
- Restore a previous version of the MCAS-S project from the *History* folder (using the same data) and see if the error persists.
- Check if the same error occurs using the same function in a project associated with different data—if this is the case this may be a bug with the software. The MCAS-S development team would appreciate feedback on this issue.

REFERENCES AND FURTHER READING

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) 2010, *Indicators of community vulnerability and adaptive capacity across the Murray–Darling Basin—a focus on irrigation in agriculture*, ABARES, Canberra.

BRS (Bureau of Rural Sciences) 2006, *Towards sustainability for Australia's rangelands—analysing the options*, report prepared by Lesslie, R, Hill, M, Woldendorp, G, Dawson, S & Smith, J, BRS, Canberra.

——2009, *Identification of areas within Australia for reducing soil loss by wind erosion*, report prepared by Smith, J & Leys, J, BRS, Canberra.

CSIRO Sustainable Agriculture National Research Flagship 2009a, *Identification of land with risk of acidification*, report prepared by Wilson, P, Baldock, J, Grundy, M, Jacquier, D, Griffin, T, Moody, P, Chapman, G, Hall, J, Maschmedt, D, Crawford, D, Hill, J & Kidd, D, CSIRO, Canberra.

——2009b, *Identification of areas within Australia with the potential to increase soil carbon content*, report prepared by Baldock, J, Grundy, M, Wilson, P, Jacquier, D, Griffin, T, Chapman, G, Hall, J, Maschmedt, D, Crawford, D, Hill, J & Kidd, D, CSIRO, Canberra.

CSIRO Water for a Healthy Country National Research Flagship 2006, *Spatial prioritisation of NRM investment in the West Hume area (Murray CMA region)*, report prepared by Hill, P, Cresswell, H & Hubbard, L, CSIRO, Canberra.

Hill, MJ, Fitzsimons, J & Pearson, CJ 2009, 'Creating land use scenarios for city greenbelts using a spatial multi-criteria analysis shell: two case studies', *Physical Geography*, vol. 30, pp. 353–82.

Hill, MJ, Lesslie, R, Barry, A & Barry, S 2005, 'A simple, portable, spatial multi-criteria analysis shell—MCAS-S', in Zerger, A & Argent, RM (eds.), *MODSIM 2005 International Congress on Modelling and Simulation, Modelling and Simulation*, Society of Australia and New Zealand, Melbourne, December.

Hill, MJ, Lesslie, RG, Donohue, R, Houlder, P, Holloway, J, Smith, J & Ritman, K 2006, 'Multi-criteria assessment of tensions in resource use at continental scale: a proof of concept with Australian rangelands', *Environmental Management*, vol. 37(5), pp. 712–31.

Lesslie, R 2012 'Mapping our priorities—innovation in spatial decision support', in Figgis, P, Fitzimons, J, Irving, J (eds.) *Innovation for 21st Century Conservation*, Australian Committe for IUCN Sydney, pp. 156–163.

Lesslie, R & Cresswell, H 2008, 'Mapping priorities: planning re-vegetation in southern NSW using a new decision-support tool', *Thinking Bush*, vol. 7, pp. 30–3.

Lesslie, RG, Hill, MJ, Hill, P, Cresswell, HP & Dawson, S 2008, 'The application of a simple spatial multi-criteria analysis shell to natural resource management decision making', in Pettit, C, Cartwright, W, Bishop, I, Lowell, K, Pullar, D & Duncan, D (eds.), *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*, Springer, Berlin, pp. 73–96.

Mackey, B, Gilmore, S, Pringle, H, Foreman, P, van Bommel, L, Berry, S & Haseler, M 2010, 'BioPrEP—A regional, process-based approach for assessment of land with high conservation value for Bush Heritage Australia', *Ecological Management & Restoration*, vol. 11(1), pp. 51–60.

GLOSSARY AND INDEX

Function	Explanation	Section
Average	The mean for each cell from data layers selected from a time series	5.1.3
Categorical data	Data that are classified into groups according to a common property. *Antonym*: Continuous data	5.1.1
Change source	*Change Source* is a right mouse click option used to restore the link to a data layer when this has been lost. A lost data link is indicated by a red cross	9.1
Classified data	Data layers previously created by users during an MCAS-S analysis (e.g. multi-way comparison) and saved in the *Classified* data folder	5.4
Coefficient of variation	A measure of dispersion to be used when comparing datasets using different units, or data with different averages using time series	5.1.3
Colour ramps	A gradual change between colours, with the intermediate colours being assigned to data classes. Colours and colour ramps can be changed	6.5.2
Composite	A map layer showing the combination of two or more map layers' data	6.4
Continuous data	Data with infinite number of possible values, such as rainfall, with the data being categorised at various points along a continuum (e.g. 0–10, 10–20). *Antonym:* Categorical data	5.1.2
Coincidence count	A multi-way analysis showing how many input criteria are met	6.3.2
Copy	Image—An exact replica of a map layer can be saved as an image Log—Extract text describing how a data layer has been classified	8.3.2 8.3.1
Correlation	The frequency of values of one layer against another calculated using a two-way analysis	8.2.3
Delete	Permanently remove a layer from the workspace	6.1.3
Discard	Defining the maximum or minimum data values and discarding values outside that range	6.2.1
Edit	The digital button in the *Function* menu pressed to enter an algebraic function for a composite layer	6.4.2

Function	Explanation	Section
Equal area	Allocates the same number of data points to each class	6.2.1
Equal interval	Groups the data into regular classes regardless of their distribution	6.2.1
Export	Option to save any layer in the workspace in a format for future use in MCAS-S or other software applications	8.1
Function	The creation of composite map layers using an algebraic expression	6.4.2
Google Earth	Showing layers in Google Earth	8.2.4
Histogram	A bar graph in the left hand interface panel showing the distribution of values in the selected dataset	6.2.1
History	Time stamped copies of MCAS-S projects are saved in a folder called *History* when the user saves the project	8.3.5
Import	An interface that lists available layers within time-series data	5.1.3
Info	A button on the interface panel that allows viewing of the metadata	Figure 6 (2.5) Figure 26 (6.2.1)
Interface panel	The left hand side panel that appears once a map layer is selected. The interface panel includes the layer name, data distribution histogram, classes, and the methods or functions used to combine layers	Figure 6 (2.5)
Install	To initially set up for subsequent use	2.2
Labels	Can refer to: – displaying labels on point files – categorical data labels from text files (mask data example) – changing class name labels	 5.5.2 5.1.1 6.2.2
Layer	A single level of data that can be combined with other layers to produce composites	5.1
Legend	Explanatory diagram of the map/data	8.3.3
Lines	A form of precise vector data detailing the connection between two points (see Overlay)	5.2
Log	Can refer to: – producing a function using a logarithm – classifying data using a logarithmic scale – a record of processing steps that can be copied and pasted as text	 Table 2 (6.4.2) 6.2.1 8.3.1
Mask data	Gridded layers used to restrict the area of analysis or define regions for reporting Multi-way mask	5.3 6.3.2

Function	Explanation	Section
Maximum and discard	Defining the maximum data values and discarding values above that	6.2.1
Metadata (see *Tip files*)	Data about data (i.e. basic information about the source of the data being used)	5.5.4
Minimum and discard	Defining the minimum data values and discarding values below that	6.2.1
Move	Relocating data layers in the workspace	6.1.1
Multi-way	A form of comparison when the spatial association of two or more data layers is required	6.3.2
Natural breaks	A method for classifying data inputs	6.2.1
Open	Open a project Open a data layer	2.3 5
Overlay	Data points that help the user identify locations (e.g. cities, roads, regions) but do not have values associated to them	5.2
Own data	Data that the user independently acquires and processes for use in MCAS-S	5.5
Points	Specific vector data detailing coordinates see overlay	5.2
Primary data	The main input data in MCAS-S, comprised of raw data, can be been assigned into classes	5.1
Print	Producing a paper hard copy of the graphics	8.3.4
Radar plot	A small graph used in a multi-way comparison made up of a series of vectors, each representative of a data layer value	6.3.2
Range	The difference between maximum and minimum values of the data for time-series data	5.1.3
Raster data	Spatial data expressed in a matrix of cells; used for data that gradually changes along a continuum. *Antonym:* vector data	5.5.1
Reclass	Classifying data values in a new order	6.2.3
Reporting	A function for generating statistics on a user-defined masked area, for a point, or to find a correlation	8.2
Resize	Changing size of data layers in the workspace	6.1.2
Save	Save a project Save an image or log Save a layer (see export) Save display settings for a layer	2.4 8.3.3 8.1 Figure 6 (2.5)
Sensitivity analysis	A method of making minor changes in the input data to see effects on the output data	7.1
Single function	A function that selects a single grid for inclusion as a layer	5.1.3

Function	Explanation	Section
Standard deviation	A measure of dispersion or variance from the mean used to classify continuous data calculated for time series data	6.2.1 5.1.3
Text (.txt) files	Files associated with raster data layers (primary or mask data) that provide labels for grid values. Categorical data have associated text files	5.5.3
Time series	Data representing the same information at a point/ points over time	5.1.3
Tip files	Brief, explanatory metadata files that accompany data	5.5.4
Truncate	To assign data below or above a designated value to the highest or lowest class	Figure 27 (6.2.1)
Two-way	A comparison that allows the user to explore the spatial association between two data layers identifying corresponding high and low values	6.3.1
Underlay	A layer as a backdrop for all other layers	6.3.3
Unhandled exception	The *Unhandled exception* window indicates that an error has been identified	9.1
User layer	A layer created by the user via their own data analysis and processing	5.6
Vector data	High-precision data to define a point, line or area. *Antonym:* Raster data	5.5.2
Viewer window	A display box that provides information on the cells within the data layer that the mouse is poised over in the display workspace	6.5.1
Workspace	The area of the screen in which all data viewing, analysis and comparison takes place	Figure 4 (2.5) Figure 6 (2.5)
Zoom	Change in screen magnification	6.1.4